DOCUMENT RESUME

ED 166 097 SO 011 477

TITLE	International Environmental Monitoring: A Bellagio Conference, February 16-18, 1977 (Revised Publication).
INSTITUTION	Rockefeller Foundation, New York, N.Y.
PUB DATE	Nov 77
NOTE	116p.; Chart on page 100 may not reproduce clearly due to small print type of original document
AVAILABLE FROM	Publication Office, The Rockefeller Foundation, 1133 Avenue of the Americas, New York, New York 10036 (free)
EDRS PRICE	MF-$0.83 HC-$6.01 Plus Postage.
DESCRIPTORS	Air Pollution Control; Case Studies; Conference Reports; *Conservation (Environment); *Cooperation; Depleted Resources; *Environmental Influences; *Global Approach; Natural Resources; *Physical Environment; *Quality of Life; Regional Cooperation; Wastes; Water Pollution Control

ABSTRACT

The proceedings of a conference on international environmental monitoring is presented, along with a commentary, reports from activity groups, and appended tabular information. Major objectives of the 25 participants from international organizations, national governments, and research institutions were to review accomplishments in global and regional monitoring since 1972, reevaluate international monitoring needs, and provide guidance to the Rockefeller Foundation in supporting international environmental monitoring efforts. An overview of systems which monitor environmental quality is provided by Ralph W. Richardson, Jr., of the Rockefeller Foundation. A report by Martin Holgate (Department of the Environment, England) identifies major topics of concern related to environmental assessment, including environmental policy, costs of environmental monitoring, deciding what to monitor, and uses of monitoring data. Two papers by Brian Martin and Frances Sella (Global Monitoring System, Nairobi, Kenya) discuss global monitoring activities. The remaining papers are concerned with lead monitoring in Finland (Sven Hernberg, Institute of Occupational Health, Helsinki), rangeland resources in Kenya (David Western, University of Nairobi), monitoring organisms in coastal waters (Edward Goldberg, Scripps Institution of Oceanography, La Jolla, California), ozone networks (R.E. Munn, Interenvironmental Research Branch, Canada), and mercury monitoring in Sweden (T. Westermark, Royal Institute of Technology, Stockholm, Sweden). A directory of conference participants is included. (DB)

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A Bellagio Conference, 1977

Conference Report

The Global Environmental Monitoring System

International Monitoring Activities

Case Studies

Lead Monitoring in Finland

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The Mussel Watch

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Mercury Monitoring in Sweden

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International Environmental Monitoring

A Bellagio Conference, February 16-18, 1977

The Rockefeller Foundation

August 1977

Library of Congress Cataloging in Publication Data

Main entry under title:

International problems in environmental monitoring.

(Working papers - The Rockefeller Foundation)
Bibliography: p.
1. Environmental monitoring--Congresses.
2. Pollution--Measurement--Congresses. I. Rockefeller Foundation. II. Series: Rockefeller Foundation. Working papers - The Rockefeller Foundation.
TD169.I576 363.6 77-10723

Published in August 1977 by The Rockefeller Foundation

Printed in the United States of America

CONTENTS

	Page
Participants	v
Introduction - Ralph W. Richardson, Jr.	1
Conference Report - Martin Holgate and Daniel Serwer	3
The Global Environmental Monitoring System - B. Martin and F. Sella	16
International Monitoring Activities - B. Martin and F. Sella	25
Case Studies	
Lead Monitoring in Finland - Sven Hernberg	60
Monitoring Rangeland Resources in Kenya - David Western and Harvey Croze	64
The Mussel Watch - Edward Goldberg	73
The WMO World Ozone Network - R. E. Munn	77
Mercury Monitoring in Sweden - T. Westermark, Arne Jernelöv and A. G. Johnels	89

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INTRODUCTION

All our hopes and plans for maintaining or improving the quality of the environment depend on an understanding of the natural systems with which human societies interact and the way in which these systems are changing over time, whether in response to natural factors or human perturbation. Monitoring systems that can quickly and accurately measure changes in the environment over varying periods of time are fundamental to this understanding. If we do not know the direction and magnitude of environmental changes, we cannot rationally decide whether corrective efforts are either necessary or effective. The vital importance of monitoring was recognized by the 1972 Stockholm Conference on the Human Environment and the 1974 Intergovernmental Meeting on Monitoring. Practical realization of its importance followed with the establishment of the Global Environmental Monitoring System (GEMS) within the United Nations Environment Programme (UNEP). The Rockefeller Foundation's active interest in international environmental monitoring has been made evident by its support of the Monitoring and Assessment Research Center (MARC) at Chelsea College, London; and of a research program at the Massachusetts Institute of Technology.

The brief experience to date with international monitoring has been enough to demonstrate that it is subject to a great many problems, whose solution requires the substantial commitment of both private and public funds, and the close coordination of efforts among governments, agencies, and institutions. The meeting, reported in this publication, was intended to promote a wider and fuller understanding of current monitoring activities and future prospects. Organized and sponsored by The Rockefeller Foundation, in close connection with UNEP, the conference was held from February 16-18, 1977, at the Villa Serbelloni Study and Conference Center in Bellagio, Italy.

The meeting had three main objectives:

a) to review accomplishments in global and regional environmental monitoring since the 1972 United Nations Conference on the Human Environment;

b) to reevaluate international monitoring needs; and

c) to provide guidance to The Rockefeller Foundation in supporting international environmental monitoring efforts in the future.

The 25 participating experts came from international organizations, national governments and research institutions. They participated as individuals and the opinions they expressed were not necessarily officially sanctioned. Furthermore, this report of their discussions has been compiled by the rapporteur and the chairman; therefore, the report should not be interpreted as representing the opinions of individual participants, of the organizations for which they work, or of the group as a whole. The Rockefeller Foundation is making the report widely available in the hope that it will prove useful to the scientists, governments, international organizations and private groups that have taken an active interest in building international environmental monitoring programs over the past few years.

Ralph W. Richardson, Jr.

CONFERENCE REPORT

Martin Holgate and Daniel Serwer

Global Environmental Monitoring: The Present View

The Global Environmental Monitoring System

GEMS, the Global Environmental Monitoring System, is the monitoring component of Earthwatch, a UNEP coordinated environmental assessment program that also includes research, scientific evaluation and review, and information exchange. Thus, in the context of UNEP, environmental monitoring is closely related to other aspects of an overall environmental assessment system that provides data for environmental management. A decision to monitor a particular environmental condition is usually based on a scientific assessment of research results; and the monitoring, in turn, will suggest new areas for research and assessment. Monitoring information is most useful when widely exchanged through mechanisms such as the International Referral Service (IRS) and the International Register of Potentially Toxic Chemicals (IRPTC).

The 1974 Intergovernmental Meeting on Monitoring recommended the following goals for a Global Environmental Monitoring System:

1) an expanded human-health monitoring system;
2) an assessment of global atmospheric pollution and its impact on climate;
3) an assessment of the extent and distribution of contaminants in biological systems, particularly food chains;
4) an assessment of critical environmental problems relating to agriculture and to land and water use;
5) an assessment of the response of terrestrial ecosystems to pressures exerted on the environment;
6) an assessment of the state of ocean pollution and its impact on marine ecosystems; and
7) an improved international system for understanding and monitoring the factors leading to disasters, and an efficient forecasting and warning system.

These goals, which are in no priority order, have guided the development and implementation of the UNEP coordinated GEMS program, which at present operates almost entirely through the UN specialized agencies. Before the formulation of these goals, international monitoring was both uncoordinated and extremely limited in extent.

At the Bellagio meeting, however, most of the discussions focussed on GEMS' activities in two major categories: (1) the monitoring of pollutants, and (2) the monitoring of ecological systems and natural resources. The term "resources" at the Bellagio meeting came to mean exclusively those resources that are in principle renewable, such as fertile soil, forests, grasslands, wildlife, and water. Nonrenewable resources, such as coal and other minerals, were not included; nor did the Bellagio discussions include the monitoring of natural disasters.

Environmental Monitoring and Environmental Policy

Environmental monitoring is not an end in itself, but an essential step in the processes of environmental assessment and environmental management. Figure 1 describes the ideal relationship between the scientific functions of research, monitoring and risk assessment on the one hand and the socioeconomic mechanisms of environmental management on the other. Of course, few environmental problems will follow precisely the path indicated in Figure 1, and in actual practice available research and monitoring results are seldom as unambiguous or as adequate as one would like them to be as support for decisions. Nevertheless, it is essential to emphasize that monitoring data are intended for use in policymaking, and that governments support environmental monitoring because they expect it to provide useful information.

The importance of environmental monitoring for policymakers was a major theme of the case studies prepared for the Bellagio meeting, and are presented in this report. These case studies describe national experiences with issues that have not yet been fully confronted at the international level. As these studies show, the contributions of monitoring results to national policies varied widely. The monitoring of environmental lead levels in Finland for example has failed to stimulate action to protect worker health, despite the clear and close connection that has been demonstrated between occupational exposure to lead and lead concentration in the blood. The monitoring of mercury in Sweden, however, has caused the government to make a small but critical change in seed-dressing formulations. Between these extremes, the Amboseli wildlife monitoring effort has been accepted as a standard for project evaluation by the World Bank. International environmental monitoring is generally even less readily accepted as a basis for policy than national efforts of the sort described in the case studies. Therefore, it was generally agreed at the Bellagio conference that special attention in formulating international programs should be paid to the special needs and concerns of policymakers.

Paying for Environmental Monitoring

On the international level, the financial resources available for the development and coordination of environmental monitoring are extremely limited. The UNEP Fund presently commits close to $2 million annually to stimulating global and regional monitoring activities, providing between 50 and 80 percent of the budgets of the efforts supported. The remainder is provided by the cooperating agencies, which include the World Health Organization (WHO), the Food and Agriculture Organization (FAO), the World Meteorological Organization (WMO), and UNESCO, as well as a variety of regional organizations.

The UNEP Fund contribution to monitoring has grown to its present size from less than $0.5 million in 1974, but it is unlikely to exceed a peak of around $5 million within the next few years. These UNEP funds are used primarily for international coordinating activities. The bulk of the actual monitoring is paid for by governments, whose support to national monitoring activities is at least ten times as great as the international funding. In addition, some important international monitoring efforts receive no UNEP assistance: weather monitoring, the monitoring of endangered species, and certain types of ocean monitoring, for example, are well-established activities on the international level that are carried on without UNEP support.

Deciding What to Monitor

The reality of limited funds means that the international community must give careful attention to priorities for environmental monitoring. GEMS has generally given priority to global and regional problems that appear to present serious harm to man or to essential components of his environment. Many of these problems are due to pollution. Developed countries have been especially interested in large-scale pollution problems such as carbon dioxide levels in the atmosphere and oil pollution in the oceans and less interested in apparently more localized problems involving various ecological systems and their management. These ecological and natural resource problems, however, are of critical importance to developing countries, which have understandably been anxious for GEMS to deal with such issues, especially when they have regional significance. The GEMS efforts to conduct a world assessment of actual and potential soil degradation and to conduct pilot monitoring activities involving the tropical forest cover and tropical rangelands in West Africa, respond to this strong interest of the developing countries.

There are good reasons to pay increased attention to ecological and resource monitoring. For one, the real difference in scale between global pollution and local resource problems has probably been exaggerated. Even global pollutants such as DDT are often manifested as regional problems, posing serious risks in limited geographical areas, or "hot spots." Conversely, the wider impact of seemingly local ecological and resource problems has been made clear by events such as the Sahelian drought and the desertification process. In addition, there is a high level of international interest in commonly occurring local or national problems. The destruction of forest cover, or wildlife depletion, for example, can become an important focus for international monitoring programs.

Ecological and resource monitoring projects are being developed by GEMS from pilot and demonstration efforts. In many cases, a sharp distinction between monitoring and research activities cannot be easily made. Monitoring programs may begin as research projects, or as inventories and surveys, and only later be extended to repetitive measurements designed to determine temporal trends. It takes a great deal of effort to determine the present extent and state of resources, their natural and man-induced variations over time, and their potential for human use, before it becomes possible to reach useful conclusions about the danger of resource degradation and the need for continuing monitoring.

In establishing priorities for monitoring pollutants, the criteria are reasonably well-established. These criteria include the following: substances with potentially dangerous chemical and physical properties, such as persistence in the environment and accumulation in living organisms; substances known to have caused harm in specific instances; substances used in ways that make high human or ecosystem exposures likely; and substances known to be acutely toxic, carcinogenic, mutagenic, or otherwise harmful. For ecological and resource monitoring, the criteria for establishing priorities might include the following: the physical quantity and economic value of the resource; the productive potential of the resource under ideal management conditions; the known rates of change and degradation of the resource; and the amenability of the resource to corrective management measures. It should be noted that in many developed countries renewable resources like soil and crops are already monitored because of their economic importance. The primary present need for international action is in monitoring in developing areas where the economic value of the resource is not as great, has not been recognized, or has not yet elicited effective action.

The function of resource monitoring is not only to prevent degradation of the resource, but also to encourage its optimal development. Here there are clear parallels with pollution monitoring: complete elimination of pollution discharges is rarely required to reduce health and environmental risks to acceptable levels. The proper function of pollution control is pollution minimization rather than elimination. Similarly, natural resources can be used without over-exploitation. Monitoring should provide much of the information needed to optimize the level, technical means, and frequency of this use.

Quality of Measurement and Sampling

It is sometimes difficult to persuade policymakers, on both the national and international levels, that it is critically important to control the quality of measurement and sampling methods in monitoring programs. As a result, some early international monitoring efforts have paid insufficient attention to two key aspects of quality control: the intercalibration of measuring systems among different countries, and the careful choice of monitoring sites.

The importance of intercalibration derives primarily from the use of a variety of measurement methods in international monitoring programs. This variety has permitted participation by laboratories with different equipment and varying levels of technical sophistication, and promoted the adoption of new techniques as they become available. Intercalibration by the exchange of samples among laboratories and by permitting some redundancy in monitoring networks is therefore important in ensuring the most accurate results.

Intercalibration, however, will prove fruitless unless sites are chosen well. Too many monitoring efforts suffer from major statistical weaknesses because the intersite comparisons are difficult to make and the sites cannot be fitted into a comprehensible pattern of variation. For example, many atmospheric monitoring stations allegedly sample urban air, but the full range of variation in urban air pollution is not known. Comparisons between cities may therefore be highly uncertain, and comparisons between urban sites and rural sites may be even more difficult.

The choice of monitoring sites, including the choice of media or organisms in which pollutants are measured, should be subject to strict, internationally approved criteria, even though operational control is at the national level. Experts in national monitoring efforts should be satisfied with the criteria, and with the system design as a whole, before international programs are launched. Without a thorough and continuing quality control effort, the interpretation of data gathered in different countries, even with the same measurement techniques, will be at best ambiguous. Therefore, although there is clearly a role for nongovernmental institutions such as MARC in research and in the development of monitoring systems, the monitoring programs themselves should be operated by governments and coordinated through appropriate intergovernmental agencies.

Special problems arise when pollutants are monitored in "indicator" organisms that serve as convenient surrogates for the human and other organisms that we are seeking to protect, as when mussels are used to monitor pollutant levels, or when pike are used to monitor mercury levels. Because of the wide inherent variability in any species and the different environments in which various populations of any species live, great care must be taken to ensure that intersite comparisons are valid. It is also critical to choose species that are sensitive indicators at the actual levels of human or ecosystem exposure: only if the levels in an indicator organism are correlated with levels in organisms that we seek to protect can the monitoring data be effective in designing practical control measures. The alternative - measuring human or ecosystem exposures directly, rather than through the use of indicators - should always be considered. Whichever option is chosen, one important way to check the data is to preserve monitoring samples so that they can later be reanalyzed in the light of new discoveries or with the use of improved techniques.

In principle, it would be desirable to achieve economies in monitoring efforts by using simgle sites for more than one international program. Thus, for example, air and water monitoring in the oceans might use the same ships. The Biosphere Reserves - extensive ecosystems still in a natural state - designated for complete preservation as part of a UNESCO program might also be used for monitoring background levels of air pollution. In actual practice, however, such multiple use of monitoring sites may be difficult because of the different criteria imposed by various programs. Nevertheless, the increasing scope and expense of international monitoring programs will surely increase the pressure for multiple use.

Some of the barriers to multiple use of sites are institutional rather than scientific, and these barriers make it difficult to coordinate monitoring efforts. International monitoring programs serve various scientific constituencies: urban air pollution monitoring, for example, serves a different scientific community from monitoring of oil in the oceans. This diversity of communities can mean potentially serious coordination difficulties at both national and international levels.

Use of Monitoring Data

The use of data from international monitoring programs can also present major difficulties. Although, in fact, action is often taken before systematic and evaluated monitoring data are available, ideally there should be a clearly understood and statistically valid assessment of the data, their trends, and their implied risks before major management costs are incurred in taking corrective action. GEMS, like many national monitoring programs, has not yet established mechanisms for the authoritative, scientific assessment of monitoring data.

Without reaching any firm consensus, the Bellagio participants discussed whether the overall assessment responsibility should be undertaken by GEMS itself, by UNEP, by other United Nations agencies, or by ad hoc scientific commissions. In any event, some such assessment mechanisms, tailored to meet the needs of different activities, will be needed in the near future, as the first data from international monitoring programs become available.

The present lack of scientific assessment accounts for the absence of conflict so far over international monitoring programs. With only a few exceptions, governments have not yet treated international monitoring programs as politically sensitive. In the future, however, conflicts may arise over the liability for damage caused to neighboring countries by transfrontier pollution or by use of natural resources. Similarly; conflicts may arise in the oceans, particularly with the increasing national control over broad offshore zones. There is no doubt of the need for more effective monitoring of ocean resources and the conditions that imperil them, of river systems, and of the mobility of air masses. Governments, however, may be reluctant to change the results of studies that provide evidence bearing on questions of liability. Scientific assessments of monitoring data, and the implications of these assessments for corrective action with national economic and political consequences, will make monitoring a much more controversial activity.

The design of international institutions to carry out scientific assessments poses serious problems. On the one hand, the need for scientific objectivity would appear to favor consultation of outstanding specialists irrespective of nationality; thus, nongovernmental mechanisms, either ad hoc or continuing, might be more appropriate. On the other hand, nongovernmental agencies might have difficulty obtaining the necessary data and other resources required. Furthermore, the assessments of such agencies might not be accepted as authoritative by governments excluded from the assessment process. Several hybrid mechanisms are possible, including the selection of suitable individuals by international agencies from rosters of government-approved experts (a procedure used by WHO); and the use of government-nominated experts who serve in their individual capacities (a procedure already in use by GEMS for some purposes, but not yet for assessments).

Whatever the final institutional solution, the need for scientific assessments of international environmental monitoring data will become critical. Two questions should be asked in the assessment effort: a) what trends do the monitoring results reveal? b) what are the risks of harm to human health, ecological systems, or other resources? Answers to these questions will point to rational decisions about future monitoring priorities. It would be senseless to continue to monitor pollutants that have been found not to pose serious risks to human health, ecological systems, or other resources.

Global Environmental Monitoring: Future Needs and Opportunities

New Projects

Many needs and opportunities for expansion of international monitoring programs involve ecological and resource monitoring. Pollution monitoring is more firmly established, but a limited number of efforts to supplement existing programs might be warranted.

Among current pollution problems, threats to the ozone layer from man-made chlorofluorocarbons and nitrogen oxides are of particular concern because of the carcinogenic potential of certain frequencies of ultraviolet (UV) light, from which man is largely protected by the stratospheric ozone. Total ozone is presently monitored, but the vertical and horizontal distributions of ozone and their fluctuations are not well known.* Moreover, UV

*The launching of the NIMBUS-G satellite in the fall of 1978 will provide such measurements on a systematic basis for the first time.

radiation is not presently monitored. Consideration should be given to the direct measurement of the ultraviolet radiation of wavelength 290-320 nanometers (usually called UV-B) that causes skin irritation (erythema). Such measurements could provide a check on the inferences drawn from other less direct research. Daily observations of UV-B measurements at noon should suffice to establish a time series. Suitable instrumentation for such monitoring is presently being investigated by WMO.

Also among the high-priority pollution monitoring efforts that might be undertaken are the monitoring of benzo(a)pyrene and other carcinogens in urban air, of halocarbons and radioactive nuclides in the open oceans, and of krypton 85 in the atmosphere, of pollution exchanges at the ocean-atmosphere interface, and of river pollution discharges into the oceans. Some of these efforts are already underway within individual countries, and as research or pilot monitoring projects on the international level.

In resource monitoring, there is broad scope for innovation. Several important research and pilot efforts are concentrated in ecologically fragile tropical areas, where monitoring of tropical soil, forest, and rangeland are priorities. The monitoring of livestock and wildlife numbers, using relatively simple and inexpensive techniques, is about to begin on a pilot basis at the international level. We should also monitor northern marginal areas, including boreal forest cover, arctic tundra, and glacial-margin biomes. These ecosystems are especially vulnerable to climatic disturbance and to direct human interference. The individual countries concerned are already doing some monitoring, but these efforts have not used common methodologies or classifications and the data generated are neither comparable nor readily retrievable on an international basis.

In addition to these tropical and arctic monitoring efforts, other possibilities for resource monitoring deserve consideration. Fire, especially in tropical regions, is a major element in ecosystem disturbance, as is the continuing expansion of inhabited land, or land occupied by major manmade projects like settlements, roads, and reservoirs. These major environmental perturbations might be monitored internationally in the future, perhaps with the assistance of satellite surveillance. Food production and drought, though monitored carefully in developed countries, have still not received the attention they deserve in many developing countries.

Toward More Effective Organization and Participation

There are two further components of the operation of monitoring programs that merit attention:

1) the problems of coordination within and among governments and international agencies; and
2) the need for increasing participation by developing countries, especially through training programs.

Different international monitoring programs serve various scientific constituencies impact air pollution monitoring serves quite a different scientific community from monitoring of oil in oceans. The diversity of communities involved can lead to potentially serious coordination difficulties at both the national and international levels. Many governments do not have the capacity to participate in the variety of international environmental programs, including monitoring programs, that are recommended to them; international organizations, such as GEMS, cannot respond to all the demands coming from governments to institute new programs. GEMS at present has no continuing advisory mechanism, other than the UNEP Governing Council, for establishing priorities among its program activities, and governments have been reluctant to establish additional international mechanisms. Similarly, national governments more often than not lack effective means to decide on monitoring priorities. As the available financial resources approach their upper limit, there will clearly be a need for both national and international mechanisms for resolving interprogram conflicts and establishing priorities.

One monitoring-related program activity that has received insufficient attention is training. Many international programs are seriously compromised by the lack of monitoring sites in developing countries. Special efforts should be made to fill these gaps both by training needed personnel and by developing measurement techniques appropriate to developing countries. MARC could well play an expanded role in such training programs, using as a basis its current efforts to develop appropriate curricula. Also important are the bilateral arrangements that the United States has established for the use of satellite data by developing countries. GEMS should continue to assist developing countries to identify appropriate training programs in environmental monitoring, in choosing measuring techniques, and in ensuring comparability with measurements being made elsewhere.

Summary Remarks

International environmental monitoring efforts are now beginning to produce some of the results that were expected of them when they attracted widespread support in the early 1970's. Especially in the area of global pollution problems, we are at the point of needing to advance monitoring programs to the stage of scientific assessment, a crucial step in making the most of the considerable investment already committed. In natural resource and ecological monitoring, the need is for more inventories and pilot monitoring projects that might be expanded in the future. These, however, require considerable financial resources.

As international funding levels off, we will have to make a variety of changes in the operation of monitoring programs and in the procedures used to decide on priorities. One key requirement will be for a mechanism - probably a small and prestigious group of government-nominated experts - to decide on overall international environmental monitoring priorities. Another requirement will be for continuing quality control efforts linked closely with research and development on new monitoring methodologies by such institutions as MARC.

No strict guidelines can be offered on the roles of private and public funding. The ad hoc arrangements for coordination used in the past have not always been ideal, but the experience gained over the past few years in cooperative and complementary efforts will provide a better basis for future work. Ultimately the bulk of the funding for monitoring comes not from private bodies or international agencies but from the national governments which are responsible for carrying out the measurement activities.

The role of nongovernmental and intergovernmental institutions is largely catalytic, and successful catalysis depends on designing scientifically sound programs that meet the perceived needs of governments and on communicating the scientific results of monitoring to governments for action. GEMS is central to this communication between the various scientific communities and governments. UNEP funds should not be used to provide continuing support for existing monitoring networks, but rather to mount new activities and to stimulate appropriate governmental responses to monitoring results.

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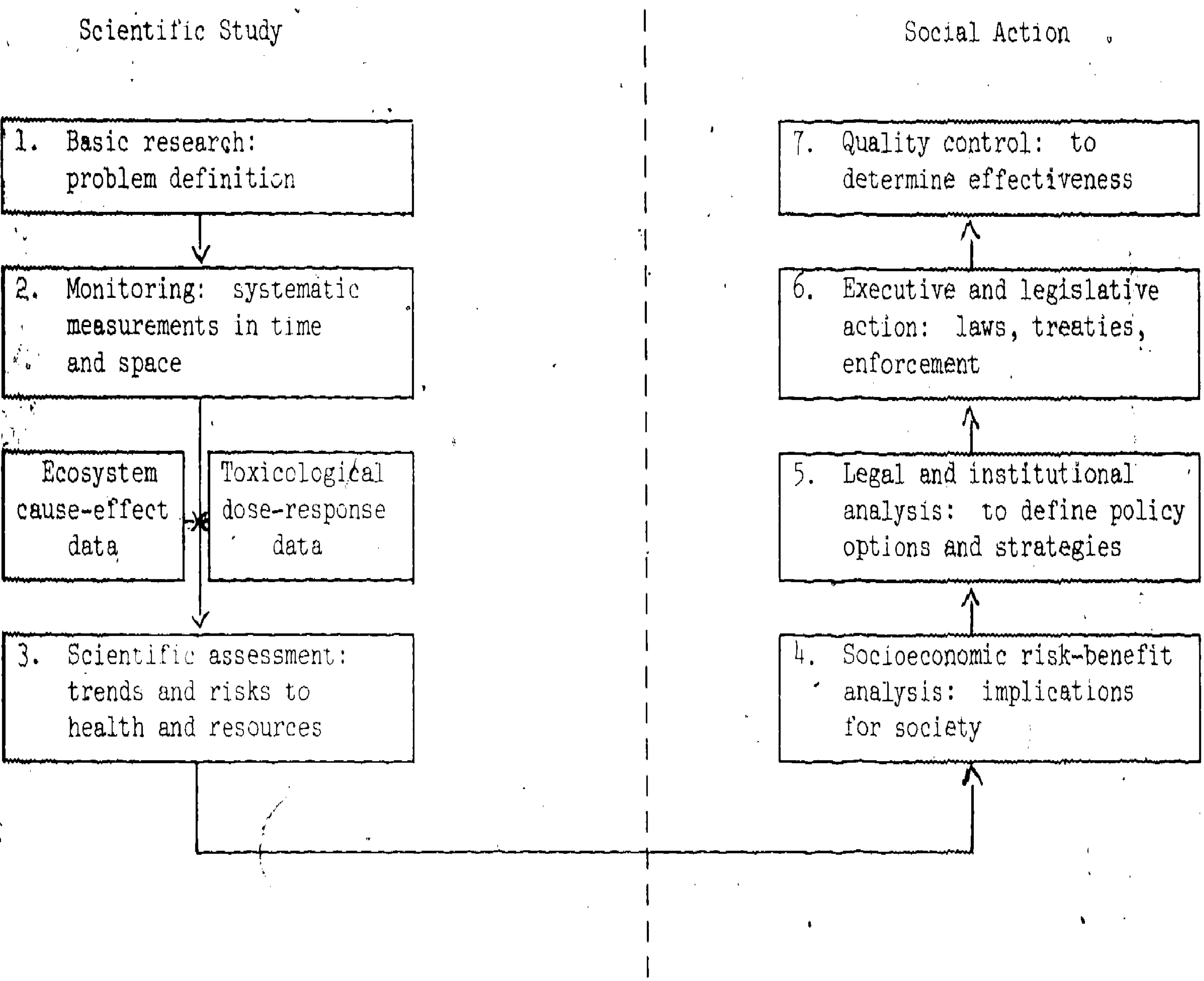
Figure 1: An Idealized View of the Role of Environmental Monitoring in Policymaking



THE GLOBAL ENVIRONMENTAL MONITORING SYSTEM

B. Martin and F. Sella

A description of the development and implementation of GEMS, the Global Environmental Monitoring System, from 1970 to the present.

The Development of the Gems Concept

Since 1970 the idea of a global environmental monitoring system had been the subject of much discussion, especially in nongovernmental circles in developed countries. Initially, the discussion focussed largely on the problem of monitoring pollutants; although ecological and natural resource problems were recognized, monitoring of natural resources was considered to be of secondary importance or, on technical grounds, premature.

The Massachusetts Institute of Technology sponsored two reports on environmental problems - the SCEP report "Man's Impact on the Global Environment" in 1970 and the SMIC report "Inadvertent Climate Modification" in 1971. Also in 1971, at the request of the Preparatory Committee for the United Nations Conference on the Human Environment (hereafter called the Stockholm Conference), the Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions (ICSU) produced a report entitled "Global Environmental Monitoring." All these reports were the work of scientists from developed countries, and emphasized developed-country problems.

As part of the preparations for the Stockholm Conference, an intergovernmental working group on monitoring (IWGM) was convened in late 1971 to define the objectives of monitoring, assess how these might be implemented and assign priorities for their implementation. The 1971 IWGM recognized several important principles, later endorsed by the 1974 Intergovernmental Meeting on Monitoring (IMM), regarding the implementation of internationally conducted global monitoring. These were:

(a) Intergovernmental cooperation in monitoring should build on the basis of existing national and international systems "to the maximum extent possible";

(b) United Nations specialized agencies should be used "to the maximum extent possible as the institutional base for coordinating and implementing monitoring programs";

(c) Priority should be given to the development of global and regional (multinational) monitoring;

(d) Monitoring systems should be designed to meet clearly-defined objectives and arrangements for the evaluation of the data must be an integral part of the design of the systems.

The IWGM provided a working definition of monitoring as "a system of continued observation, measurement and evaluation for defined purposes." This definition drew no distinction between regulatory monitoring and descriptive monitoring, nor did it make clear what was meant by "evaluation." International monitoring had always been discussed in terms of descriptive monitoring, and this understanding has been maintained. The meaning of "evaluation" as used in the IWGM definition, and in principle (d) above, was clouded to some degree after the term was used for one of the four separate functional components of Earthwatch (environmental assessment) as defined at Stockholm. However, in the context of Earthwatch the term is now taken to refer to a two-stage process - (1) validation of environmental data, i.e. a form of quality control, and (2) interpretation of the data in order to recognize significant trends in individual environmental variables, as an input to environmental management.

The IWGM report did not consider the problem of an institutional structure for global monitoring. Evidently the time was judged premature for such discussions, although one government felt it was the most important issue and should be discussed. Eventually the IWGM noted in its report that "It is essential to improve coordination mechanisms within the United Nations framework," and recommended a study to explore how coordination could best be achieved.

While the Stockholm Conference did not examine the IWGM report in any detail, it did adopt many recommendations related to specific monitoring activities, reflecting the fact that, with a few major exceptions (e.g. the World Weather Watch), no international monitoring activities were in operation at that time. However, the conference did not consider the problem of coordinating monitoring activities at the global and regional levels. Indeed, most of the recommendations were directed at individual agencies, without reference to any coordinating machinery.

Initial efforts to address the problem of coordination were made by an Inter-Agency Working Group on Monitoring, established by the Environment Coordination Board in 1973. Its report described for the first time the monitoring activities already undertaken and those being planned by the United Nations agencies. In addition, the Working Group commissioned SCOPE to plan a first phase of GEMS. The result, the most thorough analysis to date, examined the priorities for monitoring and the bases for selecting certain environmental variables as indicators of possible trends in the environment. Underlying these two reports was the assumption that, while global pollution monitoring could be launched or expanded immediately, monitoring of natural resources must be postponed until much more preparatory work had been accomplished.

During the same period, discussions also went on within governments on how best to organize international monitoring. In the United States, this led to a series of documents - the first issued in 1973, the latest in 1976[1] - which, apart from their considerable intrinsic interest, are illustrative of the evolution of thinking about international monitoring in one developed country. From rather large-scale initial blueprints, the proposals have now evolved to more manageable proportions, fairly consistent with the activities undertaken or planed under GEMS.

In 1974, the Executive Director of UNEP convened an Intergovernmental Meeting on Monitoring in Nairobi. This marked the emergence of the GEMS concept in a more realistic form. The IMM (a) recommended that the Executive Director be authorized to establish at UNEP headquarters a Director for

[1] "Early Action on the Global Environmental Monitoring System," National Academy of Sciences, Washington, D.C., 1976.

GEMS with supporting staff; (b) laid down seven program goals for GEMS; (c) listed the priority pollutants to be considered by GEMS; (d) recognized the need to monitor other, nonpollutant, environmental variables; (e) endorsed the set of objectives and principles laid down by the 1971 IWGM.

The Director for GEMS was appointed at the end of 1974 and the GEMS program activity center (PAC) was formally established in 1975 as a section of UNEP responsible for the coordination of all monitoring activities within the United Nations and for giving advice to the Environment Fund on the financial support it should provide in accordance with the views and decisions of the Governing Council.

From its inception, GEMS was conceived as a coordinated effort on the part of member states, United Nations agencies and UNEP to gather data essential for effective environmental management.

Member states, beside being the actual operators of monitoring system components, provide policy direction for GEMS activities through the Governing Council. At its third session the Governing Council requested the Executive Director to convene small groups of governmental experts to help in the design and implementation of GEMS.

At the interagency level, coordination is achieved through the Environment Coordination Board. At the fifth session of the Board, it was agreed that the role of the GEMS PAC does not extend to internal coordination of individual monitoring activities, which is the responsibility of the agency under whose auspices the activity in question is being implemented. The essential role of the GEMS PAC is to ensure coordination among individual monitoring activities. Thus the Board emphasized that the role of the GEMS PAC, while very broad, was nevertheless nonoperational.

The Implementation of the Goals

As mentioned above, the 1974 IMM laid down seven goals that GEMS should strive to meet in order to fulfill its function. They are, not in order of priority:

A. Expanded warning system of threats to human health;

B. Assessment of global atmospheric pollution and its impact on climate;

C. Assessment of extent and distribution of contaminants in biological systems, particularly food chains;

D. Assessment of critical problems arising from agricultural and land use practices;

E. Assessment of the response of terrestrial ecosystems to environmental stress;

F. Assessment of the state of ocean pollution and its impact on marine ecosystems;

G. An improved system of international disaster warning.

It is helpful in understanding how the seven goals relate to one another to note that:

(a) Goals E and F are of very general and wide application and between them largely subsume the remaining goals. For example, evidence of "environmental stress" on terrestrial ecosystems (goal E) can be seen in the impact of pollutants on climate (goal B), in contaminants in biological systems (goal C), in man's misuse of his natural resources (goal D), in environmentally induced disease (goal A), and in some of the factors contributing toward natural disasters on land (goal G);

(b) The goals can be grouped into two broad categories: those relating to pollution monitoring (A, B, C and part of F); and those relating to ecological monitoring, i.e. monitoring the stocks and conditions of various natural resources (E, D and part of F). Depending upon the type of natural disaster, goal G could fall into either category, or neither.

It is evident that the two different categories of goals require different monitoring approaches and that two different types of data will be produced, although in some limited areas overlap can be envisaged.

In the category of pollution monitoring it is possible to design monitoring activities so that analysis of each individual result can be integrated with that of related results, thereby obtaining maximum use from the data. The ultimate aims of global and regional pollution monitoring are:

(a) The determination of the levels of selected critical pollutants in particular media, their distribution in space and their trends in time;

(b) An understanding of the magnitude and rates of the mass flow of selected pollutants, and their harmful transformation products;

ERIC

(c) The provision of an opportunity for countries, including developing countries, to compare methods of sampling and analysis in order to obtain comparable results, and to exchange experience on monitoring systems;

(d) The provision, on a global or regional scale, of information essential for management decisions on pollution control.

It is more difficult to determine how to integrate the result of ecological monitoring, because of its immediate reflection on environmental management options which relate in a complex manner to population, resources and development. GEMS has approached ecological monitoring through the initiation of pilot studies to develop methodologies and make large-area, small-scale surveys of natural resources (soil, forest, rangeland). These surveys will serve to define critical areas of degradation, which may then be studied by more intensive monitoring to yield data upon which governments may wish to base corrective action.

The extent of implementation of GEMS is best gauged by looking at those international monitoring activities already undertaken or planned that are listed and outlined in the following paper, "A Survey of International Monitoring Activities." The list is not confined to activities carried out within the United Nations system, much less to those in which UNEP cooperates directly with other parties; it includes a few activities carried out by organizations outside the system, since these fill important gaps that would otherwise need to be the concern of the United Nations system. The activities have been grouped according to a simple classification, apparent from the table of contents, which is related to the program goals.

An examination of the list will show that (a) most of the international monitoring activities are the responsibility of United Nations agencies, with the major exception of certain regional activities undertaken by ECE and OECD, and particularly ICES; (b) among the activities for which United Nations agencies are responsible, virtually all of those related to pollution and ecological monitoring are being carried out or planned with the cooperation of UNEP.

It is difficult to go beyond the details given in the following paper concerning the overall plans for the implementation of GEMS, since the

ERIC

various components are in different stages of development. Indeed, some are only partly environmental monitoring in the GEMS sense. Thus the World Weather Watch, which has been fully operational for a number of years, is only partly relevant to GEMS, since some of its components, while providing essential services to the world community, are generally not required for the identification of trends in the environment. On the other hand, the activities related to ecological monitoring are, at this stage, largely of a premonitoring nature, limited to large-area, small-scale surveys aimed at identifying areas where repetitive monitoring should be undertaken.

Furthermore, it is important to realize that for some activities, such as background monitoring of pollution in the atmosphere, networks of a specified size can be envisaged and aimed at. For other activities - such as impact monitoring of air pollution - the goal is much less definite, since the program only aims at providing countries with model stations that will enable them to emplace networks of the size and quality they need. Likewise, with regard to ecological monitoring, current activities aim at providing small-scale surveys that will make it possible for individual countries to select, according to the rational criteria embodied in the developed methodologies, areas for detailed monitoring that they may decide to carry out on their own territories.

An additional complication is that, with responsibilities variously apportioned between member states and international organizations and with the extremely small international financial resources available for monitoring, planning is continually frustrated by the difficulty of matching objectives with the reality of the amounts and availability at any given time of resources of both national and international origin.

The Priority Variables

In conducting the activities set out in the following paper, the list of pollutants drawn up by the 1974 IMM was closely followed, and in some cases greatly expanded. The main pollutants that were originally listed and that are not currently being monitored under GEMS are nitrogen oxides, carbon monoxide, asbestos and reactive hydrocarbons at atmospheric impact

ERIC

stations. Plans for including those pollutants in an expansion of the air quality monitoring program are, however, being considered.

With regard to other environmental variables, the IMM recommendations were somewhat vaguer. The soil and vegetation cover monitoring activities that are being undertaken or planned under GEMS will make major contributions to the knowledge of the state, potential and degradation of natural resources, particularly in areas that may be affected by the desertification process.

Flow of Data from Collection to Final Assessment

The collection of data under the various monitoring activities belonging to GEMS is the ultimate responsibility of member states. The data are then assembled centrally under procedures that vary depending on the activity that has produced them. The following paper contains examples of how the centralization of the results from individual activities is achieved.

Each activity contains provisions to ensure that data gathered by different laboratories and in different countries can be compared with each other. Thus intercalibration under forms appropriate to each activity is an essential element of the operation and for some programs involves a substantial portion of the international financial resources commited to a project.

Data whose quality has been ensured are published, again according to procedures that vary with the activities generating them, and thereby fall into the public domain. Background and impact air pollution monitoring data are thus being published yearly by WMO with the Environmental Protection Agency and National Oceanographic and Atmospheric Administration of the United States and by WHO, respectively.

In many cases, data thus published must accumulate for many years before meaningful analysis and interpretation can be undertaken. This can be done by individual scientists or institutions and by the United Nations agencies responsible for the international coordination of the individual activities.

UNEP is planning to examine these analyses from sets of related activities (e.g. health-related monitoring, monitoring of vegetation and soil cover, etc.) through the work of governmental expert groups. In addition to reviewing and collating these analyses, government experts will be asked to evaluate the need for and the adequacy of the activities reviewed and to make recommendations for their improvement, expansion or phasing out.

INTERNATIONAL MONITORING ACTIVITIES

B. Martin and F. Sella

A survey of the most important international monitoring activities through January 31, 1977. The survey identifies the agency or agencies with primary responsibility for each monitoring program, and specifies the purpose of the program, its planned future development, and its expected results. A list of abbreviations appears at the end of this paper.

Activity Group 1: Ecological Monitoring

Monitoring of the Earth's Soil and Vegetation Cover

World Assessment of Soil Degradation

A world assessment of soil degradation is being undertaken by FAO and UNESCO in cooperation with UNEP with the following objectives: to assess actual and potential soil degradation by compiling existing data; to develop an appropriate methodology for monitoring degradation; to prepare guidelines for data accumulation suitable for mathematical modelling; to investigate the use of remote sensing techniques; and to study refinements of meteorological data which determine climate aggressivity and soil degradation hazards in different ecological zones. This work makes extensive use of the soil map of the world produced by FAO, UNESCO and the International Society of Soil Science.

The soil degradation map was undertaken in direct response to recommendation 20 of the Stockholm Conference. Work to date has produced a draft map of soil degradation on the scale 1:5,000,000 for Africa north of the Equator; data upon which that map will be based have also been used in the production of a larger scale map (1:200,000 to 1:500,000) to demonstrate desertification for the 1977 Conference on Desertification. By the end of 1978 the assessment of both soil degradation and degradation hazards for Africa north of the Equator and the Middle East will have been completed at the 1:5,000,000 scale. The global assessment is expected a year later.

During 1977, critical areas in the tropical zone of North Africa requiring more intensive monitoring will be identified, particularly with regard to soil salinization and alkalinization.

Tropical Forest Cover Monitoring

A pilot project, undertaken by FAO in cooperation with UNEP has as its objectives:

To undertake in four adjoining countries (Togo, Benin, Nigeria, Cameroon), over a period of three years, monitoring of the forest cover using a methodology developed during an earlier phase;

To obtain data on both the present forest cover and its quantitative and qualitative changes with time;

To refine, test and possibly adjust the general methodology in the light of the various logistic problems encountered;

To prepare to extend monitoring to the rest of the tropical belt.

The pilot activities started at the end of 1975. By the end of 1977 the first forest cover data should be available, and by 1979-1980 these results and those from the rangelands project mentioned below will make possible the application of the refined monitoring methodologies and vegetation classifications in other tropical areas of the globe. It is hoped that a full inventory of the cover for most of the tropical belt will be available by the mid-1980s. This will be dependent upon the continuing availability of Landsat-type satellite data and other available resources, as well as cooperation from the countries involved.

Rangelands Monitoring

Pilot project on monitoring of rangelands (planned):

This pilot project, to be undertaken by FAO in cooperation with UNEP, is primarily designed to develop and demonstrate appropriate methodology for the surveying and monitoring of rangelands. The secondary objectives include the writing of a manual of instruction, the training of interested country representatives and the identification of operational problems likely to arise in the wide implementation of the developed methodologies.

The first phases, including reconnaissance of suitable areas, are expected to start in 1977. Close cooperation will be maintained between the pilot project and FAO's EMASAR program, which involves the use of monitoring data in the Ecological Management of Arid and Semi-Arid Rangelands; and with UNESCO's Integrated Project on Arid Lands, which aims to identify the causes of ecological degradation and desert encroachment in arid zones.

Global Appraisal of Land Resources Potential by Agro-ecological Zones

In 1976 FAO initiated a three-year appraisal of the suitability of land for agricultural purposes in different agro-ecological zones of the world. Suitability of land for the production of main crops will be rated qualitatively in terms of anticipated yields. It is expected that comparisons of the yields of the main crops by agro-ecological zones will clearly identify both major problem areas and prime production areas and will indicate where maximum returns may be expected from modest, i.e., "on farm" inputs.

The Monitoring of Water Resources

The International Hydrological Decade (IHD) and the International Hydrological Programme (IHP)

During the IHD, which ended in 1974, a number of local and regional stations throughout the world collected water resources data in an effort to understand regional and local water balances, which constitute subsystems of the global water cycle. Data on sediment discharge were also collected, and the results of this overall world study have been published by UNESCO in a series of reports. Information is available on the transportation of sediments in about 250 rivers in over 40 countries, and on water discharge for about 1,200 stations in about 70 countries. More detailed information on river discharge is being accumulated in the UNESCO/UNEP World Register of Rivers discharging into the oceans.

Within the framework of the new, long-term International Hydrological Programme (IHP) launched by UNESCO in 1975, work will continue on various scientific projects, including water balance studies, research into hydrological regimes, etc. Data from the above-mentioned network will be used, as appropriate, together with information from the WMO network of operational hydrology stations.

Monitoring Services for Hydrology

WMO's objective is to coordinate measurements of basic hydrological elements at national meteorological and hydrological stations all over the world, and to coordinate the collection, transmission, processing, storing, retrieval and publication of basic hydrological data. Methods will be developed for observation, data transmission and processing, and hydrological forecasting, in order to promote operational hydrology at the national level. To this end, WMO is preparing a Hydrological Operational Multipurpose System (HOMS) to be installed at the national or regional (basin-wide) level to facilitate the supply of data.

World Glacier Inventory

The World Glacier Inventory was launched by UNESCO during the IHD and is implemented in cooperation with UNEP and with the International Commission for Snow and Ice. The main aim of the inventory is to obtain an estimate of the world's solid water resources.

International Cooperation on Water Balance in Europe

At a workshop organized by UNESCO and WMO in September-October 1976, proposals for a program of international cooperation on water balance in Europe were developed. The proposals are concerned with standardization of measurements and methodology in studies of water cycles, and include an important monitoring component. Of particular interest will be the studies of the water balance in basins extending over territories of several countries. The program will be considered further at the second UNESCO/WMO Conference on Hydrological Problems in Europe to be held in Brussels in September 1977.

World Survey of Isotope Concentration in Precipitation

Since 1961, IAEA, in cooperation with WMO, has acted as the collecting agency for data on the distribution of tritium, deuterium and oxygen-18 in precipitation. Over the years, more than 100 meteorological stations in 65 countries and territories have collected monthly precipitation samples. These are sent for analysis to the IAEA

ERIC

hydrological laboratory in Vienna, or in some cases to cooperating laboratories in other countries. At present, 121 stations are actively participating in this monitoring network.

Quarterly reports of data from the collection stations and laboratories are processed for computer storage on magnetic tape. This tape is used for a biannual publication prepared by IAEA, entitled "Environmental Isotope Data." Five volumes of data have so far been published, covering the period 1961-1970. The data are being used in hydrological studies tracing the geochemical history of water.

The Monitoring of the Biosphere

The Man and the Biosphere (MAB) Programme (UNESCO)

Several national research projects within the international MAB program, launched by UNESCO in 1971, are concerned with small-scale monitoring of ecosystems. Most of these fall within those MAB projects which deal with ecological effects of human activities on resources of lakes, rivers, marshlands, deltas and coastal zones, and with effects of pollution on the biosphere. Pilot monitoring activities are also carried out in several MAB Biosphere Reserves (see below). An up-to-date inventory of national MAB projects, which will be available from UNESCO in 1977, will reveal more details of these monitoring activities. Current information shows that pilot studies on various types of monitoring are distributed among 35 countries in North and South America, Europe, Africa, the Middle East and the South Pacific. These relate to: nutrient cycling in forest and grassland ecosystems, eutrophication and related nutrient flow, effects of land use on water quality, incidence and effects of atmospheric precipitation of pollutants on terrestrial and aquatic ecosystems.

Within the MAB program, an important activity related to monitoring is the establishment of Biosphere Reserves. To date a total of 118 such reserves have been formally designated. Many of the reserves are being established in remote areas where they will be available for monitoring of the conditions in natural ecosystems, and of pollutants at the background level. Further cooperation between UNESCO and UNEP will be established in order to make ultimate use of these reserves for operational monitoring activities.

Wildlife Sampling and Analysis Program

From 1972 to 1975, OECD has undertaken continued monitoring of the content of PCB, DDT, TDE, DDE and mercury in certain marine, fresh-water and terrestrial fish and wildlife species. The following countries have joined in this exercise: Austria, Belgium, Canada, Japan, Finland, France, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States. Data obtained in country reports have been computerized and analyzed statistically since 1974. Results have been considered annually by an expert group, and data for the final year (1975) were processed in the spring of 1976. A full examination of the results of the three- to four-year undertaking is being conducted, and the final report is expected during 1977.

Wildlife Monitoring

The Survival Commission of IUCN is attempting, with the financial support of the World Wildlife Fund and UNEP, to monitor the changing status of various endangered species of wildlife through information collected on individual species by specialist groups throughout the world, and by the use of other methods.

Impact Monitoring of Pesticide Residues

Plans for monitoring pesticide residues in the environments of developing countries were developed during an FAO/UNEP expert consultation in 1975. Implementation of the plans might begin in 1977 on a two- or three-year pilot study basis. Resultant data should add to the knowledge of the level of pesticide residues gained in associated activities.

Monitoring of Marine Resources

Living Marine Resources

For many years, the International Council for the Exploration of the Sea (ICES) has been systematically collecting data on fish catches as an index to fish stocks in the North East Atlantic, the adjacent waters of the Arctic and the Baltic Sea. The fish stocks and catches presently monitored include herring, cod, haddock, whiting, sole, saithe (coalfish), mackerel, salmon, and deep sea shrimp. Some shellfish, such as the Norway lobster, are also monitored. Reports are issued annually containing detailed statistical information on catches and estimated stocks. In 1974, ICES produced a survey of fish resources in the North East Atlantic which included data on the life history of the fish species in addition to summary data on catches for ten years (1962-1972) and the state of exploitation of each species.

Activity Group II: The Monitoring of Pollutants

Subgroup 1: Health-Related Monitoring

The Monitoring of Air Pollution

Air Quality Monitoring

The basic objectives of this activity, which is undertaken by WHO in cooperation with WMO and UNEP are:

To establish a system for monitoring air pollution in urban and industrial regions around the globe; to arrange international exchange of information from this system on levels and trends of air pollution;

To improve the validity and comparability of air quality measurements made by member countries and organizations through the development and implementation of monitoring-quality-assurance program, including reference methods, reference standards, monitoring guidelines and interlaboratory comparison studies;

To provide technical assistance to member states to strengthen their air-pollution-monitoring through training courses, fellowships, consultations, guidelines and supply of additional equipment, with special emphasis on the need of those developing countries that have serious air pollution problems.

Data collecting started in 1973 as a pilot study, with 14 developed countries participating in the measurement of sulphur dioxide and suspended particulates in urban areas. WHO published the 1973-1974 data in 1976 and will continue publishing data on an annual basis under the title "Air Quality in Selected Urban Areas." A manual on urban-air-quality-monitoring and data-reporting procedures was published by WHO in 1976, and a manual on the selection of suitable sites for monitoring in urban areas is being prepared.

The current phase, which lasts unti mid-1977, will attempt to involve 50-60 countries, with emphasis on training and data quality. Phase 2 (mid-1977 to the end of 1978) will concentrate on introducing measurements of additional pollutants such as carbon monoxide, oxidants, heavy metals absorbed on particles, nitrogen oxides, etc. Increased emphasis will also be given to linking air quality measurements to epidemiological studies carried out in the cities concerned. The present network is presented at the end of this report.

Arrangements have been made by EEC to ensure that data on air pollution being collected in cities and industrial areas within the EEC are brought into this project. Data are being channelled through the WHO European office to WHO headquarters for inclusion in the publication on "Air Quality in Selected Urban Areas." An additional element of the EEC survey in six of its member states is a study of the relationship between air pollution and respiratory ailments in children.

Deposition and Transmission of Air Pollutants in Europe

It has gradually become evident that air pollution may affect large geographical areas far beyond the major sources of pollution. During the years 1973-1975 OECD carried out an extensive research project in most countries of Western Europe on the extent of deposition and the magnitude of long-range transportation of SO_2. About 70 stations monitored SO_2, and the resulting data were compared with those amounts of SO_2 estimated to have been transported over long distances from their sources. The results are expected to be published in 1977.

In the light of this study, and of the recommendations of the Conference on Security and Cooperation in Europe, ECE, in cooperation with WMO and UNEP, is developing a plan for a "Program for Monitoring and Evaluation of Long-Range Transmission of Air Pollutants in Europe." The basic objective of the program is to provide governments with information on concentrations and extent of deposition of air pollutants (SO_2, NO_x and particulate matter) in Europe, as well as on the magnitude and significance of the long-range transmission of these pollutants and their flows across boundaries. The plan, if approved, will start in 1977 with the participation of the Governments of eastern and western European countries.

Inventory of Institutions in the ESCAP Region with Capabilities for Air and Water Pollution Monitoring

The National Environmental Engineering Research Institute, Nagpur, India, with cooperation from UNEP, is preparing an inventory of institutions in the ESCAP region with capabilities for air and water pollution monitoring. The inventory is expected to be issued in 1977. This is a first step to build up improved capability for environmental monitoring in the ESCAP region.

The Monitoring of Water Quality

Global Water Quality Monitoring System

The basic objectives of the network, which is operated by WHO in cooperation with UNESCO, WMO and UNEP, are:

(a) To collect, compile, analyze and disseminate comparable information on water quality parameters of public health importance as well as requisite hydrological elements;

(b) To strengthen water quality monitoring in member states as part of their water quality management and to assess transport levels and trends of particularly hazardous water pollutants on a global basis.

A detailed work plan has been developed by WHO in collaboration with WMO, UNESCO and UNEP. Cooperation will be established with FAO and ISO. Preparations will be concluded in December 1977, and operations are scheduled to start early in 1978. The project as presently conceived makes no provision for surveillance of water issuing from drinking water treatment plants.

Monitoring of Inland Waters for Eutrophication Control

In 1973, eighteen OECD member countries joined in a four-year program on monitoring of inland waters to provide information for the control of eutrophication. The final stage of integrated data processing and assessment of results will take place in 1977.

The Monitoring of Food and Animal Feed

Both FAO and WHO have long been involved in the standardization of norms for food quality through their joint activities in the Codex Alimentarius Commission.

Food and Animal Feed Contamination Monitoring Program

The basic objectives of this activity, which involves FAO and WHO with UNEP, are:

(a) To develop an international comprehensive food-and-animal-feed-contamination monitoring program with components to assure comparability of data, data collection, review, evaluation and dissemination;

(b) To encourage governments which already undertake contaminating monitoring activities to participate and share information;

(c) to assist governments, particularly those of developing countries, wishing to initiate or strengthen such programs.

An initial pilot project involving ten countries (three of which will be developing countries) will monitor chlorinated hydrocarbons in certain milk products, and lead in some vegetables and fish products, in order to determine levels and intercalibrate methodologies. Operations are due to start in July 1977. Additional contaminants, such as aflatoxins, will be monitored later. The first set of data should be published in late 1978, followed by a review meeting of the pilot phase in 1979.

The Monitoring of Pollutants in Targets

Monitoring in Body Fluids and Tissues

A UNEP/WHO Government Expert Group meeting will be convened in April 1977 to consider all health-related monitoring activities carried out in air, food and water under GEMS, and to integrate them into a coherent program. To that end, the group will consider proposals for additional activities to be initiated before the end of 1977, including the monitoring of certain pollutants such as lead, cadmium, mercury and organochlorine compounds in body fluids and tissues. This should make it possible to assess directly or by proxy the exposure of suitable samples of the population to those pollutants and to relate exposure to environmental levels.

Monitoring of Human Milk Composition

Within the mother and child health program, WHO is carrying out a two-year survey of variations in the quantity and quality of human milk, depending on nutritional, physiological and geographical circumstances. Chemical analyses will include the determination of arsenic, cadmium, lead and chlorinated pesticide residues. The results will provide information on the pollutants intake of breast-fed children and, indirectly, on the exposure of lactating mothers.

Monitoring Pollutants in Human Hair

Through participation of laboratories in 15 countries in all continents of the world, IAEA is at present studying methods for systematically monitoring certain chemical elements in human hair, using the technique of neutron activation analysis. These activities may provide an important input to the exposure monitoring activities referred to above.

Assessment of Levels and Effects of Ionizing Radiation

Since 1955, coordination of measurements of levels of radioactivity in the environment and of radiation tissue doses from all sources, and evaluation of the data on a global basis in terms of risks of genetic and somatic effects to man, has been the responsibility of the United Nations Scientific Committee on the Effects of Atomic Radiation, which reports on this at irregular intervals to the General Assembly. The latest substantive report was issued in 1972 (Ionizing radiations: levels and effects. United Nations publication, Sales No. E.72.IX.17). The next one, due in 1977, will comprehensively cover the whole field of risk of radiation from natural, medical, and industrial sources.

Monitoring of Health Effects of Environmental Agents

Monitoring of the Health Effects of Pollutants

While the specific effects of pollutants at the high doses met in acute poisonings and other accidents are generally well known, information on the detrimental effects of the low levels of pollutants to which populations as a whole may be exposed over long periods of time is scanty. This is because the effects, if any, are infrequent and often nonspecific. Health effects are therefore best examined through epidemiological studies, but clues as to etiology can also be obtained by systematically following trends in the prevalence of specific diseases and in the incidence of specific causes of death. WHO is currently studying ways and means to carry out this type of monitoring through a more thorough examination of routine health and vital statistical data than is feasible in most countries.

Subgroup 2: Climate-Related Monitoring

Monitoring Climate and Climate Variability

Climate-related monitoring involves two types of activities:

(a) Monitoring climate and climate variability through observations of irradiation and other physical parameters in the atmosphere and those parameters in the biosphere and hydrosphere which have a direct or indirect impact on climate and its fluctuations.

(b) Monitoring pollutants and other compounds (such as CO_2) in the atmosphere and in precipitation, both at high (impact) and low (background) levels, for the purpose of assessing amounts and trends in amounts, with a view to analyzing their effect on local and global climate and climatic variability. Such monitoring, however, is essential also for studies of local and long-range horizontal transport of pollutants as well as for evaluation of the interchange of these pollutants with other media such as fresh water, oceans, soil and biota.

The World Weather Watch

The World Weather Watch (WWW), launched by WMO in 1967, is basic to WMO monitoring enterprises, and involves three elements: the Global Observing System, the Global Telecommunication System and the Global Data-Processing System. The first of these ensures that observations of various physical parameters (air pressure, temperature, wind, precipitation, etc.) are made every few hours at fixed international times at a network of stations covering as far as possible the whole surface of the globe. At present, the synoptic network comprises some 8,500 land stations. In addition, more than 800 stations around the world carry out upper-air observations, and about 7,500 merchant ships and 10 ocean weather stations provide data from the oceans. Data are also received from aircraft, and from geo-stationary and polar-orbiting meteorological satellites.

Within a few hours, all these observations are processed by high-speed computers and made available for use in weather forecasting and climate studies. The data are collected, processed and stored in national, regional and world centers, the latter located in Melbourne, Moscow and Washington, D.C.

All WMO members participate actively, and nonmembers are invited to do so. In any given country, WWW contributes meteorological support services depending on the local needs and also supports the specialized monitoring activities mentioned below. WWW also involves the WMO program for monitoring background air pollution, forms the basis for the WMO/ICSU Global Atmospheric Research Program (GARP) activities, and supports WMO's tropical cyclone activities.

Network of Climatological Stations

In addition to the WWW stations which provide real-time data, there are more than 100,000 stations that observe meteorological elements for application in studies of climate and its variability. WMO has arranged for standardization of measurements, processing and publication of selected data. Storage and publication of data by countries is usually on a monthly basis.

Network of Stations for Observation of Solar Radiation

More than 600 stations in 78 countries make regular measurements of incoming and outgoing radiative energy at the surface of the earth. Through WMO, the measurements from these stations have been coordinated to form a worldwide network. The data are published annually by the Main Geophysical Observatory in Leningrad.

Network for Observations of Atmospheric Ozone

The objective of this network, supervised by WMO and cosponsored by the International Ozone Commission, is to monitor, in a coordinated manner, the variations in total ozone amount in the atmosphere, initially for studies of troposphere-stratosphere energy exchange processes and other energy balance research. These data from 70 stations in 21 countries have become an invaluable tool also in studies of the possible impact of man's activities on the ozone layer. The data have been published annually, since 1963, under the auspices of WMO by the Atmospheric Environment Service, Ottawa, Canada.

Monitoring for Modelling of Climate Changes

A major objective of GARP is to develop numerical models of the atmosphere and the ocean, on the basis of which changes in the earth's climate can be explained and predicted. The WMO/ICSU First GARP Global Experiment (FGGE) will fill gaps in the existing WWW global observation system by arranging for additional observations over the oceans and by using more meteorological satellites. Preliminary studies have shown that it is crucially important to the experiment to add observations, particularly in the tropics.

Many of the ships contributing to the FGGE experiment will lack the necessary equipment for monitoring essential upper air physical properties. UNEP has agreed to cooperate with WMO in purchasing this equipment. Specially designed equipment is to be provided for six such ships from a number of developing countries operating in the tropics. FGGE is scheduled to start in January 1979.

Monitoring of Mass Balance and Fluctuations of Glaciers

The World Glacier Inventory activity was launched by UNESCO during the International Hydrological Decade and is implemented in cooperation with the International Commission for Snow and Ice (ICSI) and, since 1976, with UNEP. The program aims at standardizing the information on glacier volume and mass balance available on a national basis to make it compatible for use in a worldwide computerized system. It further aims to fill remaining gaps in global coverage, and to produce a global summary of all data. This undertaking will obviously provide valuable information about the world's water resources and for studies of the world water balance. Untimately, a selection of reference glaciers is to be made in various parts of the world to form the basis for a future system for monitoring glacier fluctuations in relation to climatic change. A temporary technical secretariat for the inventory has been established in the Department of Geography of the Swiss Federal Institute of Technology in Zurich. During the first phase of the project, fairly complete information has been collected from glacier areas in Canada, the Union of Soviet Socialist Republics, the United States and the Himalayas. More limited information has been collected so far from 45 countries.

Under the auspices of ICSI, and with support of UNESCO, data dating from 1960 on fluctuations in glacier tongues has been collected by the Zurich institute. Publications containing this information have been issued for the years 1961-1965 and 1966-1970. A new volume for the period 1971-1975 is in preparation.

Further Plans for Climate-Related Monitoring

The further requirements for monitoring of climate and climate variability are currently being studied by WMO and UNEP, in particular within the WMO/ICSU GARP program. UNEP is planning to convene between the fifth and the sixth session of the Governing Council, a Government Expert Group on Climate-Related Monitoring to provide an overall plan for monitoring in this area.

Monitoring of Pollutants in Relation to Climatic Changes

Monitoring Background Pollution in the Atmosphere

In 1970, WMO began to develop a network of worldwide observations of atmospheric pollutants and their concentration at the low background level, particularly those liable to affect weather and climate. In 1971, this network became part of WWW. UNEP has cooperated with WMO since 1974 in the expansion of this activity.

The stations in the process of being established in this network are of three types:

(a) Baseline stations for monitoring, at very low levels of concentration, significant constituents of the atmosphere on a global basis;

(b) Regional stations for monitoring long-term changes in atmospheric composition caused by changes in regional land-use practices;

(c) Regional stations with expanded programs for monitoring additional pollutants where this is feasible.

The minimum monitoring program at baseline stations includes turbidity of air and precipitation chemistry, including analysis of SO_4, CI, NH_4, NO_3, Ca, Mg, Na, K and heavy metals content, alkalinity, conductivity, pH, and CO_2 in air. At regional stations, the minimum program includes turbidity of air and precipitation chemistry. Baseline stations and regional stations with expanded programs have the option of monitoring also SO_2, H_2S (or total sulphur), NO and NO_2, NH_3, particle composition, CO, CH_4, N_2O, O_3 (total and at the ground), heavy metals in air, and Aitken nuclei.

In 1974, WMO in cooperation with UNEP began to expand the existing WMO network, particularly in developing countries. By mid-1976 the network included 120 planned or established stations in 59 countries, plus 10 baseline stations in five countries with four more in the planning stage. In this connection, WMO, in cooperation with UNEP and the Kenya government, is conducting a feasibility study for establishing a baseline station on Mount Kenya. With UNEP assistance, 12 regional stations in 10 countries have so far been equipped. A WMO Manual for Sampling and Analysis Techniques for Chemical Constituents in Air and Precipitation was published in 1974. Training seminars have been organized in Latin America and Asia, and assessment procedures are under study.

The first of several planned comparisons of analysis techniques for constituents in precipitation was organized by the United States Environmental Protection Agency in 1975/1976. WMO, in cooperation with UNEP, has also arranged for one central laboratory, the Scripps Institution for Oceanography, La Jolla, California, to ensure that all stations monitoring atmospheric CO_2 can calibrate their measurements against a common standard. The United States has published data on precipitation chemistry and turbidity for the years 1972, 1973 and 1974. From 1975 onwards, CO_2 data from baseline stations are expected to be included.

Global Ozone Research and Monitoring

A first phase of this activity is currently being carried out by WMO, in cooperation with UNEP. The basic objectives are to plan and eventually establish a program for monitoring the global distribution of ozone and of atmospheric trace substances which have an impact on the ozone budget, and to monitor solar ultra-violet radiation.

A number of stations selected from the existing WMO network of regional stations for observation of ozone, and the WMO baseline stations, will be included in the program. During 1977, a manual on ozone observations will be published and comparisons of ozone spectrophotometers will be carried out. Further developments will take into account the results of the UNEP expert group meeting on the ozone layer held in Washington, D.C. in March 1977.

Subgroup 3: Ocean Monitoring

In the marine environment, monitoring activities primarily involve organizing observations through multinational cooperation, in order to obtain information about levels and trends of pollution on regional and global scales. The pollutants of concern are those that can endanger human health, have harmful effects on living organisms, or influence the exchange of energy and matter between ocean and atmosphere.

Present activities are largely confined to pilot projects for developing methods of observation in order to be able to implement operational monitoring on a larger scale. Much of the work will be carried out in connection with the overall environmental studies of regional sea areas, such as the Mediterranean, the Caribbean, the Red Sea, etc.

Monitoring Pollutants in Regional Seas

UNEP is developing action plans for regional sea areas around the globe. These plans include monitoring activities. The first plan to have been adopted by governments is the Action Plan for the Mediterranean, but activities are in the planning stage for the Red Sea, the Gulf of Aden, the Caribbean, etc.

For about 10 years, ICES has carried out extensive studies of marine pollution, including monitoring activities in the North Sea, and, in cooperation with SCOR, in the Baltic. In 1974, the North Sea studies were extended to the Oslo Commission and ICNAF areas. ICES progress is reported to the United Nations system through IOC and its Working Committee for GIPME. An IOC/ICES Working Group is drawing up general guidelines for implementing regional baseline studies of marine pollution, and requirements for monitoring. A report will be published shortly, and GIPME will be responsible for keeping it up to date.

A number of national activities have been undertaken in the North Pacific by the United States, Japan and Canada for their own purposes.

The Mediterranean

The UNEP-Coordinated Mediterranean Pollution Monitoring and Research Program is part of the Mediterranean Action Plan approved by governments in Barcelona in 1975. It comprises seven pilot projects, dealing mainly with coastal waters, and involving baseline studies and monitoring of oil and petroleum hydrocarbons in marine waters; baseline studies and monitoring of metals (particularly mercury and cadmium), DDT, PCBs and other chlorinated hydrocarbons in marine organisms; research on the effects of pollutants on marine organisms and their populations, and on marine communities and ecosystems; coastal transport of pollutants; and coastal water quality control. These projects are being executed primarily by national institutions (70 centers in 15 countries) in cooperation with FAO (GFCM), IOC, WHO, WMO and IAEA. An additional pilot project dealing with levels of pollutants in the open waters of the Mediterranean and with the biogeocycle of the most important pollutants has been added to the program. UNEP support includes training, provision of equipment, organizing intercalibration, and preparing technical guidelines. In October 1976, a meeting of the Interagency Advisory Committee on the Mediterranean program met to review progress on the seven pilot projects and to coordinate future activities. The first review meeting of results and maintenance services will be held in mid-1977 and the final review meeting is scheduled for December 1978.

A related project includes a UNEP-initiated collaborative study of Pollutants from Land-Based Sources in the Mediterranean, which involves the cooperation of ECE, FAO, UNIDO, UNESCO, WHO and IAEA. The objective of the project is to provide the governments of the Mediterranean coastal states with appropriate information on the type and quantity of pollution from major land-based sources and rivers, and on the present status of waste-discharge and water-pollution-management practices. During the first phase of the project, an inventory of land-based sources of pollution discharging into the Mediterranean was prepared. The common methodology for data collection and interpretation was agreed upon at an interagency meeting, Geneva, June 1976. The results of the first phase were reviewed at the first meeting of the Planning Committee which was called by UNEP in October 1976. During the second phase of the project, now under way, collection of data and the assessment of all pertinent information will be the two major activities.

The North Sea

In 1967, ICES began collecting information from member countries about their studies of marine pollution. The resulting International Study of the Pollution of the North Sea included a baseline study of the physical, chemical and biological fate of pollutants in the North Sea. The pollutants included petroleum, chlorinated hydrocarbons, halogenated hydrocarbons and metals, particularly mercury, lead, copper and zinc.

The following pollutants are also being studied according to an agreed plan: sewage, industrial waste, toxic substances from industries, dumping activities and atmospheric fallout. There has been considerable progress in the development of methodology for monitoring pollutants in sea water and sediments. There is also in progress a special baseline survey of pollutants in fish and shellfish in which 10 laboratories in eight countries participate, using intercalibrated methods. First results have been published in Cooperative Res. Rep. No. 39 (ICES, 1973, 74).

The Baltic

Studies of pollutants in the Baltic have progressed along lines similar to the North Sea. Earlier studies of pollutants were followed by a baseline study in 1974/1975 involving all seven countries surrounding the Baltic. The standards from the North Sea were utilized so that the results of the two studies are comparable. The pollutants analyzed were similar, but the organisms chosen were somewhat different. Results will be published in 1977. A number of more limited studies will culminate in 1977 with a large-scale multidisciplinary open sea experiment, BOSEX-77, in which scientists from all Baltic countries will participate. This will provide the knowledge needed for the monitoring and control measures to be

ERIC

taken by the Helsinki Convention for Pollution Control of the Baltic, which is expected to become operative in the near future.

The North East and North West Atlantic

Baseline data on pollutant levels in living resources, and the addition of pollutants to the Oceans, are now being gathered in the North East and North West Atlantic, as a result of the Oslo Convention for the Prevention of Marine Pollution from Ships and Aircraft. This is the largest co-ordinated survey of its kind carried out to date. All countries bordering the North Atlantic have agreed to participate. The major effort has been concentrated on cod and hake. It is evident that the study of pollutants in the North Atlantic is much more difficult than in the North Sea, but it is being attempted. The results will be published in late 1977.

Monitoring of Open Ocean Waters

Integrated Global Ocean Station System (IGOSS)

The objective of IGOSS, a joint undertaking of IOC and WMO, is to provide information on the ocean and its interaction with the atmosphere, and to support research on processes in the oceans. The information sought relates to physical and chemical variables. The system aims at providing rapid collection of data from various parts of the world's oceans, rapid transmission or relay to designated centers for processing and products (e.g., forecasts, charts), and the distribution of products to users according to stated user requirements. Data acquired are stored at data centers for archival processing to satisfy the needs of those conducting studies and research.

Meteorological Monitoring Services to Marine Activities

IGOSS complements the marine meteorological monitoring activities which WMO, as part of WWW, has carried out for many years. In this global oceanic observing system, a variety of physical parameters in the atmosphere and in the top layers of the ocean are monitored and reported worldwide in real-time. The backbone of the system is the 7,500 merchant ships and the 10 ocean weather stations mentioned above.

IGOSS Pilot Project on Marine Pollution (Petroleum) Monitoring

This activity, undertaken by IOC and WMO with the cooperation of UNEP, is designed to initiate an internationally coordinated program for marine pollution monitoring in selected ocean areas. The purpose of the program is to acquire and exchange comparable data, so that periodic assessments can be made of the state and degree of contamination of the marine environment by oil slicks, tar-balls and dissolved petroleum hydrocarbons.

About 40 countries have agreed to participate in this pilot enterprise, most of them through nominated national coordinators. A methodology for monitoring dissolved petroleum hydrocarbons in the upper layers of the ocean has been developed and applied, but methods appropriate for deep water still need to be developed. A first training course for staff in participating laboratories was organized in September 1976. Required equipment has been provided to some laboratories.

After two years of activity, it has been concluded that sufficient interest exists to justify a two-year extension of the pilot activities. By the end of 1977, a scientific data evaluation will be undertaken by a subgroup of experts. Comparison procedures are to be introduced and additional countries are expected to participate in the next phase.

World Register of Rivers Discharging into the Oceans

A World Register of Rivers Discharging into the Oceans was started by UNESCO in cooperation with UNEP in 1974. Information on the distance of monitoring stations from the mouth, the drainage area and the average yearly water discharge is being collected for 270 rivers which meet one of the following criteria:

(a) Water discharge of more than 10 km^3/year;

(b) Drainage area of more than 100,000 km^2;

(c) A population in the river basin exceeding 2,000,000 people.

At present, data are available from 49 countries for which a list of important rivers is prepared. The rivers currently included in the register contribute about 60 percent of the natural dissolved input into the oceans by rivers. The first completed edition of the register is expected in 1977.

A second phase of the register, now being considered for cooperation with UNEP, involves a large-scale water quality monitoring program to estimate the pollutant discharge by rivers into the ocean. This exercise would focus on the largest rivers of the world plus some smaller rivers which drain from highly polluted areas. In these rivers suspended sediment quality should also be monitored in addition to various pollutants. Additional data on water quality will be obtained through regional activities, such as the Collaborative Study of Pollutants from Land-Based Sources in the Mediterranean.

The register exercise is closely related to the activities of and is guided by a joint Working Group on River Inputs to Ocean Systems (RIOS) established by SCOR on behalf of the GIPME program of IOC and with representatives from SCOR, ACMRR, ECOR, IARS and UNESCO.

A Plan for Monitoring Background Levels of Selected Pollutants in Open Ocean Waters

This plan has been developed by IOC, UNEP and WMO. The Executive Committee of WMO and the Executive Council of IOC approved the concept, and a revised draft of the plan was submitted by UNEP to governments for comments in December 1976.

The long-term objectives are to organize observations in the open ocean through multinational cooperation, in order to obtain information about the long-term changes and trends in the background levels of the more common pollutants in the ocean that (1) may endanger human health, either directly or through harmful effect on living organisms, or (2) influence the exchange of energy and matter between ocean and atmosphere. The following pollutants are proposed for monitoring in open ocean water: heavy metals (especially mercury and lead), halogenated hydrocarbons, natural (biological) surface-active agents, and a limited program on petroleum hydrocarbons, to supplement the IGOSS Pilot Project. The methodology will obviously draw heavily upon the experience gained in the regional and national activities mentioned above. The final plan with comments of the governments will be submitted for approval of the governing bodies of the participating organizations in early 1977. If approved, operations would start in early 1978.

Activity Group III

Monitoring Natural Disasters

Both in the organization of appropriate systems to forecast and warn of natural disasters and in the organization of relief work after the disaster, the acquisition and processing of a great deal of real-time data are necessary. Existing data sources must therefore be modified and expanded in many parts of the developing world where the monitoring and data collection system for these purposes is inadequate. Ongoing activities must focus either on the establishment of real-time monitoring systems where they do not exist, or on the improvement of those which are inadequate. At present, operational systems exist for tropical cyclones and tsunamis. In addition, records of events are being kept for earthquakes, floods, volcanic disasters and avalanches.

Monitoring Tropical Cyclones

For more than ten years, WMO has coordinated activities to predict and mitigate the effects of tropical cyclones by timely warnings. Vulnerability analysis is carried out by means of studies of meteorological and other relevant data for storms which have occurred in the past in the area concerned. An adequate system, however, also requires monitoring and real-time forecasting. Monitoring involves collecting data from the WWW networks of surface and upper-air observing stations, interpretation of satellite cloud pictures, and the use of weather radar observation and aircraft reconnaissance. Such basic information is essential for forecasting the intensity of the cyclone, its direction and speed of movement, the strength of winds, etc.

WMO is concerned particularly with the improvement of these techniques which are now in use in various areas in the Far East.

International Tsunami Information Center

The Tsunami Warning System in the Pacific is operated by the United States National Weather Service, near Honolulu. The system consists of seismological and tidal instruments in Hawaii and around the Pacific Ocean.

On the basis of seismic evidence, the Tsunami Warning Center issues a statement which informs the public that an ocean-floor earthquake has occurred, and where, and that the possibility of a tsunami exists.

When confirmation of an actual tsunami is received, the Tsunami Warning Center issues a tsunami warning, alerting local warning systems of the approach of a potentially destructive seismic sea wave and repeating tsunami times of arrival for all locations.

IOC maintains an International Tsunami Information Center, which works closely with the Warning Center in Honolulu, and which is responsible for giving technical advice on the establishment of national warning systems and for evaluating their performance. An International Coordination Group for the Tsunami Warning System in the Pacific coordinates the development of the monitoring system and maintains a data acquisition, storage and retrieval system.

Forecasting Floods

WMO carries out additional activities in which WWW data are applied. The most important is related to hydrological forecasting of floods. Through the Operational Hydrological Program of WMO, advice is given to countries with flood-prone areas for the establishment of the hydrological monitoring networks and data collection systems that are necessary to assist in forecasting floods.

Activity Group IV

Research and Development in Environmental Monitoring

Monitoring and Assessment Research Center (MARC)

Under the auspices of ICSU/SCOPE a center was established at Chelsea College in London in 1974 to research various aspects of environmental monitoring. The work is carried out with the active support and cooperation of UNEP and the Rockefeller Foundation. The activities of MARC are grouped in four main subject areas:

(a) Research requirements for monitoring and evaluation;

(b) Regional monitoring needs;

(c) Approaches to monitoring via the dynamics of environmental processes (e.g., the dose commitment concept evolved by the United Nations Scientific Committee on the Effects of Atomic Radiation);

(d) Time perspectives of environmental change.

The most important research area as far as GEMS is concerned is (c) above. The problems of the relationship between pollutants in various media, and the pathways of pollutants from one media to another, need to be studied with appropriate modelling techniques. Because many so-called pollutants, such as heavy metals, occur as part of natural geochemical cycles as well as by man's inputs, it is important to establish the natural environmental variability of pollution levels, independent of human activities (activity (d) above). For this purpose, data collected in years before appropriate monitoring was started are being analyzed.

Recently, MARC has taken up the problem of measuring a variety of variables in different media, e.g., air, water, biota, at the same monitoring station (multipurpose or integrated monitoring), and cooperation has been established with WMO to investigate the possibility of organizing such monitoring at the WMO background air pollution stations.

Man and the Biosphere Program (UNESCO)

UNESCO is developing a collaborative project, MAB project No. 14, entitled "Pollutant Dynamics and Biotic Response in Ecosystems," which is concerned with monitoring the effects of pollution on the biosphere. Participating scientific groups will undertake to follow agreed procedures for a basic (minimum) program, with innovative research encouraged at a more complex level. The two classes of pollutants selected for study are organochlorines and trace metals; the sites will be within MAB Biosphere Reserves or at WMO baseline or regional stations. Emphasis will be put on information exchange, cross-checking of samples, and standardized procedures.

Ocean Monitoring Methodology

ICES has had long experience in standardizing oceanographic instrumentation, in developing methods for monitoring fish stocks and training others in their use, and in promoting cooperation between national laboratories. In developing methods for pollution monitoring, ICES and IOC have prepared guidelines for carrying out essential baseline studies. Intercalibration, to permit comparability and joint interpretation, is a basic ICES principle.

Appendix 1

WHO/UNEP AIR QUALITY MONITORING PROJECT: CURRENT NETWORK

WHO Region	Country	City	Number Stations 1/	Comparison Stations 2/	Site Identification
African Region	Kenya	Nairobi	2		Completed
	Nigeria	Lagos	2		Completed
	Senegal	Dakar	2		Completed
	United Republic of Cameroon	Douala or Yaoundé	2		In progress
Region of the Americas	Brazil	Sao Paulo	3	x	In progress
		Rió de Janeiro	3		In progress
	Canada	Vancouver	3		Completed
		Toronto	3	x	In progress
		Montreal	3		In progress
		To be decided	3		
	Chile	Santiago	3	x	Completed
	Colombia	Bogota	3		Completed
		Medellin	3		Completed
		Cali	3		Completed
	Cuba	Havana	3		Completed
	Mexico	Mexico City	3		In progress
	Peru	Lima	3	x	Completed
	United States of America	New York	3		In progress
		Chicago	3	x	In progress
		Los Angeles	3		In progress
		Houston	3		In progress
		St. Louis	3		Completed
	Venezuela	Caracas	3		Completed
Eastern Mediterranean Region	Egypt	Cairo	3	x	Completed
	Iran	Teheran	3	x	Completed
	Iraq	Baghdad	2		Completed
	Israel	Tel-Aviv	3		Completed
	Pakistan	Lahore	2		Completed

WHO/UNEP AIR QUALITY MONITORING PROJECT: CURRENT NETWORK (cont.)

WHO Region	Country	City	Number Stations 1/	Comparison Stations 2/	Site Identification
European Region	Belgium	Brussels	3	x	Completed
	Czechoslovakia	Prague	3		Completed
	Denmark	Copenhagen	-		-
	German Democratic Republic	Leipzig			-
	Germany, Federal Republic of	Frankfurt	3		Completed
		Düsseldorf	-		-
	France	Paris	-		-
		Lyons	-		-
	Greece	Athens	-		-
	Ireland	Dublin			-
	Italy	Rome	3		Completed
		Milan	-		-
	Morocco	Casablanca	-		-
	Netherlands	Amsterdam	3		Completed
	Norway	Oslo	-		-
	Poland	Warsaw	-	x	-
	Spain	Madrid	3		Completed
	Sweden	Stockholm	3		Completed
	Turkey	Ankara			-
	United Kingdom	London	3		Completed
		Glasgow	-		-
	USSR	Moscow	-	x	-
		Leningrad	-		-
		Charkov	-		-
		Sverdlovsk	-		-
	Yugoslavia	Zagreb	3		Completed

WHO/UNEP AIR QUALITY MONITORING PROJECT: CURRENT NETWORK (cont.)

WHO Region	Country	City	Number Stations 1/	Comparison Stations 2/	Site Identification
South East Asia Region	India	Bombay	3		Completed
		Calcutta	3		Completed
		New Delhi	3		Completed
	Indonesia	Djakarta	-		-
	Thailand	Bangkok	2		Completed
	Sri Lanka	Colombo	-		-
Western Pacific	Australia	Melbourne	3		Completed
		Sydney	3		Completed
	China	Not decided	?		?
	Hong Kong	Hong Kong	3		Completed
	Japan	Tokyo	3		Completed
		Osaka	3		Completed
	Malaysia	Kuala Lumpur	2		Completed
	New Zealand	Auckland	3		Completed
	Philippines	Manila	3		Completed
	Republic of Korea	Seoul	3		Completed
	Singapore	Singapore	3		Completed
Approximate Totals	50	70	200		

1/ Three stations per city represents ongoing operation, 2 stations a new installation.

2/ A comparison station is one where locally used methods for a given region will be run simultaneously with WHO comparison methods (see WHO Manual on Selected Methods of Measuring Air Pollutants).

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Appendix 2

WMO/UNEP MONITORING OF BACKGROUND AIR POLLUTION

List of Stations

WMO Region	Country	Number of regional stations (located or established)	Number of baseline stations (planned or established)
Region I (Africa)	Algeria	1	
	Egypt	2	
	Ghana	1	
	Kenya		1 (being studied)
	Malawi	1	
	Nigeria	1	
Region II (Asia)	Afghanistan	1	
	India	10	
	Iraq	2	
	Japan	1	
	Pakistan	3	
	Sri Lanka	1	
	Thailand	2	
	USSR (Asia)	3	1
Region III (South America)	Argentina	1	1 (being studied)
	Brazil	1	
	Chile	2	
	Colombia	2	
	Ecuador	1	
	Paraguay	1	
	Peru	2	1 (being studied)
	Venezuela	1	

WMO/UNEP MONITORING OF BACKGROUND AIR POLLUTION

List of Stations (cont.)

WMO Region	Country	Number of regional stations (located or established)	Number of baseline stations (planned or established)
Region IV (North America)	Barbados	1	
	Canada	8	3
	El Salvador	1	
	Guatemala	1	
	Honduras	1	
	Nicaragua	1	
	USA	10	4
Region V (South East Asia and the Pacific)	Australia	1	1
	Indonesia	1	
	Malaysia	1	
	Philippines	1	
Region VI (Europe)	Austria	3	
	Belgium	2	
	Bulgaria	1	
	Czechoslovakia	1	
	Denmark (with Greenland)	4	
	Finland	2	
	France	5	
	German Dem. Rep.	1	
	Germany, Fed. Rep. of	3	
	Hungary	1	
	Ireland	1	
	Israel	2	
	Italy	4	1

WMO/UNEP MONITORING OF BACKGROUND AIR POLLUTION

List of Stations (cont.)

WMO Region	Country	Number of regional stations (located or established)	Number of baseline stations (planned or established)
Region VI (Europe)	Jordan	1	
	Netherlands	1	
	Norway	2	
	Poland	1	
	Portugal	3	
	Romania	1	
	Spain	1	1 (being studied)
	Sweden	3	
	Switzerland	1	
	Syria	1	
	Turkey	1	
	United Kingdom	1	
	USSR (Europe)	2	1
	Yugoslavia	3	

Appendix 3

PARAMETERS TO BE MEASURED IN THE GLOBAL WATER QUALITY SYSTEM

1. BASIC PARAMETERS

Parameter	Rivers	Lakes	Ground waters
Temperature	+	+	+
pH	+	+	+
Conductivity	+	+	+
Dissolved oxygen	+	+	+
Ammoniacal nitrogen	+	+	+
Nitrate nitrogen	+	+	+
Biological oxygen demand	+	+	-
Permanganate value	+	+	+
Chloride	+	+	+
Suspended matter	+	+	+
Volatile suspended matter	+	+	+
Alkalinity	-	-	+
Total hardness	-	-	+
Fluoride	-	-	+
Phosphate	-	+	-
Chlorophyll a	+	+	-
Faecal coli	+	+	+
Ecological survey (artificial substrate)	+	+	-

II. PARAMETERS OF GLOBAL SIGNIFICANCE

Parameter

Cadmium

Mercury

Organohalogens

Organotins

Mineral oil

III. OPTIONAL PARAMETERS

Parameter

Total organic carbon

Chemical oxygen demand

Methylene blue active substances
(anionic detergents)

Chromium

Nickel

Lead

Zinc

Copper

Arsenic

Boron

Sodium

Cyanide

Total oil

Faecal streptococii

LIST OF ABBREVIATIONS

ACMRR	Advisory Committee of Experts on Marine Resources Research (FAO)
BOSEX	Baltic Open Sea Experiment
CINECA	Cooperative Investigation of the Northern Part of the Eastern Central Atlantic
DDE and TDE	Analogues of DDT
DDT	Dichloro-diphenyl-trichloroethane
ECE	Economic Commission for Europe (United Nations)
ECOR	Engineering Committee on Oceanic Resources
EMASAR	Ecological Management of Arid and Semi-Arid Rangelands (FAO)
EPA	Environmental Protection Agency of the United States of America
ESCAP	Economic and Social Commission for Asia and the Pacific (United Nations)
FAO	Food and Agriculture Organisation of the United Nations
FGGE	First GARP Global Experiment (WMO/ICSU)
GARP	Global Atmospheric Research Programme (WMO/ICSU)
GFCM	General Fisheries Council for the Mediterranean (FAO)
GIPME	Global Investigation of Pollution in the Marine Environment
HOMS	Hydrological Operational Multipurpose System (WMO)
IAEA	International Atomic Energy Agency
IAPSO	International Association of Physical Sciences of the Ocean (IUGG)
IARC	International Agency for Research on Cancer
IARS	International Association of Research Scientists
ICES	International Council for the Exploration of the Sea
ICNAF	Intergovernmental Commission for North Atlantic Fisheries
ICSI	International Commission for Snow and Ice
ICSU	International Council of Scientific Unions

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IGOSS	Integrated Global Ocean Station System (IOC/WMO)
IHD	International Hydrological Decade
IHP	International Hydrological Programme (UNESCO)
IOC	Intergovernmental Oceanographic Commission
IPAL	Integrated Project on Arid Lands (UNESCO)
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
IUGG	International Union of Geodesy and Geophysics
MAB	Man and the Biosphere Programme (UNESCO)
MARC	Monitoring and Assessment Research Centre, Chelsea College London (ICSU/SCOPE)
OECD	Organization for Economic Development
PAHO	Pan American Health Organization
PCB	Polychlorinated Biphenyls
RIOS	River Inputs to Ocean Systems (SCOR)
SCOPE	Special Committee on Problems of the Environment (ICSU)
SCOR	Scientific Committee on Oceanic Research (ICSU)
UNDRO	Office of the United Nations Disaster Relief Coordinator
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
WHO	World Health Organization
WMO	World Meteorological Organization
WWW	World Weather Watch (WMO)

LEAD MONITORING IN FINLAND

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A description of Finland's program to measure the exposure of its citizens to dangerous levels of lead in the environment and to develop a rational public policy based on the monitoring results.

Early effects of lead exposure have been the subject of research in the Institute of Occupational Health for more than ten years. Exposure levels formerly thought to be quite safe were gradually shown to cause hematological and neurological dysfunctions. Dose-response relationships, using the concentration of lead in blood as the indicator of dose, have been established for some of these effects. This knowledge, together with the general concern over the lead problem in the early 1970's raised the following questions:

a) What is the exposure level of the general population in Finland?

b) What additional exposures are associated with particular occupations, and where does there exist a definite risk of poisoning?

c) What effects can be expected at the prevailing exposure levels, and what are their probabl frequencies in different settings?

d) What administrative measures are warranted to reduce exposure and to ensure regul monitoring of populations with excessive exposure?

In order to answer these questions, "chunk" samples - populations from selected areas - were drawn from the general population and representative statistical samples were selected from various occupational groups. In all, nearly 1,400 people representing the general population and about 2,200 industrial workers were studied. The general population included inhabitants of an industrial area with heavy lead population, street sweepers, traffic policemen, and downtown, suburban and rural residents. The workers came from 30 different industries.

The concentration of lead in whole blood (Pb-B) was chosen as the main indicator, since there is general agreement that this variable best reflects concurrent exposure. In addition, the activity of erythrocyte delta-aminolevulinic acid dehydratase (ALA-D) was measured in most subjects; the concentration of ALA in urine was also measured from the industrial workers. Lead-in-air measurements were available from downtown and suburban locations in Helsinki, and from one rural sampling site. In addition, an ad hoc dietary study was carried out in one of the rural locations by measuring the daily lead intake from food and beverages during three days, using a double-portion technique.

Since we knew that blood lead measurements are vulnerable to serious methodological errors, careful controls were applied from the very beginning. Precision was checked by analyzing all samples in duplicate. In addition, duplicates were regularly intermixed with the samples without the knowledge of the laboratory personnel. The analytical error ranged between 1.1 and 2.0 μg/100 ml. The blind samples had a slightly higher error, about 0.5 μg/100 ml. Accuracy was continuously checked with samples to which a known amount of lead had been added. The repeatability of the method was controlled by freezing one aliquot and analyzing it a few months later. Both the accuracy and the repeatability were satisfactory, with errors of only a few μg's.

In addition, we took part in several interlaboratory comparison programs. In general, the results were quite satisfactory. If there was any systematic trend towards differences, our method gave results slightly on the high side.

From the organizational point of view there were few problems. There were some nonrespondents the general population, but there was no reason to believe that this phenomenon introduced any bias, since people generally know very little of their exposure to lead. Other problems were caused by the fact that minor occupational exposure to lead is very common, and a thorough occupational history in connection with the sampling often resulted in the exclusion of the subject from the "normal" population because of such exposure.

The occupational survey experienced one major organizational problem. The available registers of workers were incomplete and partly outdated. The coverage of small enterprises was especially poor. Very few, if any, employers protested against having their workers examined, although some refused to believe that their workplace had any lead exposure. After we had explained that even minor exposure was of interest, the argument was usually settled.

From the results of our examinations, it became evident that the exposure level of the general population was very low compared to other countries and that practically no differences existed between the urban and rural populations. The only exceptions were those people living in an industrially polluted district, and even there no hazardous individual levels were found. We concluded that under the conditions prevailing in Finland, very little could be gained by reducing the lead content of gasoline.

By contrast, there were strong indications in favor of action to reduce industrial lead emissions. The occupational survey gave a fairly good picture of the exposure levels in the industries studied. The "classical" lead industries topped the list, but high individual values were occasionally seen even in occupations where no exposure to lead was thought to occur. We estimated from this study that about 1,000 workers have a risk of contracting overt poisoning at any given time (about 50 cases are actually reported per year), and that about 20,000 workers, or 1 percent of the country's labor force, have PbB's in excess of 40 µg/100 ml at any given time. Since our most recent results have shown indications of slight neuropathy even in workers whose PbB's have never exceeded 50 µg/100 ml, there is a definite need for regular monitoring of all workers occupied in conditions where their PbB can exceed 40 µg/100 ml.

Lead workers in Finland have had compulsory medical examinations since 1962. Their coverage has been rather poor, but some improvement has occurred

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during recent years. The Institute performed 6,000 PbB analyses in 1974, 8,000 in 1975, and 12,000 in 1976. These figures show that many workers needing monitoring are not covered by the present system.

In the sphere of public health, the most important administrative measure was reduction of industrial emissions. The authorities reacted quickly and the emissions were reduced drastically. In our opinion, there was no need for reducing the lead content of gasoline, and no measures have been taken so far.

The occupational survey provided detailed data on the need for monitoring in various situations. It also pinpointed the situations where technical improvements and other measures to reduce exposure were especially warranted. However, in spite of repeated promptings, the National Board of Labor Protection has done nothing at all to correct the situation so far.

With hindsight, the monitoring program appears to have been quite adequate. Fewer samples would have given less reliable information.

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MONITORING RANGELAND RESOURCES IN KENYA

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A case study of monitoring program in the Amboseli National Park area of Southern Kenya. Beginning in 1976, the monitoring program was intended to provide baseline data as a basis for rational land use planning in an ecologically fragile area in transition to more intensive human use.

Introduction

The area with which our case study is concerned is Ilkisongo, a subsection of Maasailand in Eastern Kajiado District, Southern Kenya. The area routinely monitored covers 8,500 square km (km^2) of semi-arid rangeland, bordered on the south and north by agricultural regions with higher rainfall. Our interest centers on Amboseli National Park and the pastoral regions which fall within the Amboseli ecosystem, but the agricultural regions are included in our purview.

Semi-arid rangelands throughout Kenya are dominated by pastoral peoples. In Amboseli the Maasai have subsisted on a traditional livestock economy until the last two or three decades. Until recently, little was known of their movement patterns, and their mode of subsistence pastoralism was understood in no more than anecdotal fashion. In recent years it was evident that their economy was changing, but it was unclear whether the apparent increasing dissonance among the various elements was due to changing climate, human population or overgrazing by livestock. The problem was, in other words, similar to that in the Sahel. There was no baseline information on human and livestock numbers, their movements and the changing patterns over time. There was no data on primary production or the availability of water resources. Without such information it was impossible to answer the most basic questions about the state of pastoral economies or environments.

Pastoralism has been compatible with the use of rangelands by wildlife, at least when extensive areas are available. The worldwide attention given to East African wildlife in recent years has led to efforts to conserve the major wildlife ecosystems. In addition, wildlife has become a primary source of revenue, particularly in Kenya. However, even less information existed on wildlife ecology and resources than on pastoral economies. National parks throughout East Africa have almost invariably been established without such information. The park boundaries have frequently had little relevance to how the animals used the area. The absence of data has furthermore precluded cost-effectiveness studies in deciding how to allocate land between pastoral and wildlife uses.

Specific Objectives and Monitoring Aims

Monitoring was started in Amboseli in 1967 and extended in 1973 to cover the entire Ilkisongo area.[1] The objectives were to provide baseline data on which land use planning could be based, and to provide data for studies on the ecological dynamics of pastoral and wildlife populations.

Monitoring of the type we describe here is of both immediate and long-term value. We therefore stress both at this stage and will return to elaborate on the long-term significance. Inductive or descriptive objectives are attainable in the short-term with little effort; deductive or predictive objectives require long-term sampling at greater cost.

Inductive or Descriptive

Each sample of the ecosystem presents a density distribution map of each species under study, including humans and livestock. Primary resources on which animals depend are mapped at the same time. Each sample thus gives an instantaneous occupance map of each species in relation to others and in relation to various resources. Sequential samples give some insights into patterns of occupance, patterns of animal and resource association, and seasonal patterns as well as those changing more gradually through time.

This initial description is fundamental to both planning and later detailed studies into causality. From the time-sequence maps occupance data can be used to map units of land into regions, the basis of land use planning. All too often, as happened in Amboseli, land allocation is politically necessary before a functional understanding of the pattern of land use is attained. In such cases recognition of the pattern, and planning on that limited basis, can be accomplished quickly.

Deductive or Predictive

Ultimately the most effective planning is based on predictive science. Knowing the causes of patterns enables allowance to be made for future events not measured in the short term and for the knowledge to be applied elsewhere.

The sequential sampling in Amboseli is used to define regions. Each region is then studied in greater detail by sampling representative units. By such a 'nested' sampling design hypotheses are constructed on the causes of patterns. Experiments can then be designed specifically to test these hypotheses. For example various species, including cattle, appear to have a limited range from water. The hypothesis that their range is limited by water can then be tested experimentally and the outcome can provide a powerful predictive tool for range management.[1]

Methods

The specific design of the Amboseli monitoring scheme is based on methods described elsewhere and now commonly in use in East Africa.[2,3,4,5,6.]

The entire 8,500 km^2 is overlaid by 5 km coordinates, giving cells of 25 km^2 each. Every 6 to 8 weeks a 10 percent sample of Ilkisongo is flown by a series of North-South transects through the center of each tier of grids. The aircraft, a high wing Cessna, carries 4 personnel: a pilot-navigator, two animal recorders seated in the rear, and an environmental observer in the co-pilot seat. The recorders count all animals falling between streamers attached to the wing strut which, with the height of the aircraft held constant at 90m by reference to a radar altimeter, defines a

300m wide strip on the ground. A precise sample can therefore be counted; photography and tape recorders aid in accurate counting.

The environmental observer records the condition of vegetation and other variables both by visual observations (calibrated against ground truth plots) and spectrophotometry. All data is subsequently recorded on computer forms and the data plotted as maps on line-printer output. Population estimates are also mapped.

Ground observations have periodically been used in various areas when greater resolution has been needed. A particular area in which people and animals concentrate during the dry season has been the subject of 25 percent ground sample each month.[4] This procedure has provided considerably greater resolution on animal distributions in relation to resources, though no better estimate of most animal populations than is provided by aerial methods.[8]

Using data from the large scale counts, regional units have been constructed and small scale sampling plots established within representative areas of each. A sampling plot is $300m^2$ and each month standing crop estimates are made based on height and cover measurements.[5] Samples are taken for protein and fiber determination from which digestive coefficients of the pasture can be calculated,[7] as well as water content.

Two sets of ERTS satellite imagery have provided a basis for comparison with both aerial and ground information. The results suggest that the imagery provides data compatible with estimates of green biomass of vegetation.

Results and Applications

A few examples of the results relevant to planning are given for later discussion purposes.

From density distributions it was possible to evaluate the following:

a) the range of each species and species associations;
b) differences in occupance data of livestock and wildlife;
c) areas of maximum wildlife usage;
d) areas of maximum livestock usage;
e) the distribution of each species in relation to permanent water and green forage.

These data were used to define the boundaries of a national park which gave maximum conservation effectiveness at minimum cost to livestock. It had earlier been shown that net revenues were greater from tourism than livestock sales over this unit of land.[9, 10] The results from the livestock censuses were employed in establishing the optimum size for ranches in the area, allowing flexibility of seasonal movement.[11]

The allocation of land in terms of wildlife and livestock interests was the main outcome of the monitoring program. However, management efforts are necessary to integrate what are fast becoming conflicting forms of land use - ranching and conservation. Suggestions on management measures have been outlined in detail elsewhere.[10] Wildlife could still leave the national park and utilize the adjacent ranches, but at a cost to the ranchers. This "opportunity-cost" has been calculated from occupance maps of the total wildlife biomass, translated in its livestock equivalents and the market value calculated.[10] It has been recommended that the ranchers be paid a corresponding compensation fee from park revenues. Such provisions are now possible within the new wildlife act and should soon be implemented in Amboseli.

Monitoring data has also been put to use within the national park. Amboseli is suffering congestion from tourists, but largely because of concentrated use around the visitor lodges rather than absolute over-use. A mere 10 percent of the park receives 80 percent of all visitor use, not because animals are localized, but because the roads do not disperse tourists over the available area. From monitoring information, it has been possible to define circuits within the park that disperse visitors in patterns closer to the patterns of animal occupance.[12] This means that for a given level of visitor-visitor disturbance, numbers and revenues can be maximized, an important reason for tourist planning in a developing nation.

The final example of application arises from data gathered over a longer time span. Together with a few isolated counts prior to 1967, continual monitoring has done much to record the changing human livestock economy.[13] Initially, increases in subsistence wealth resulted from water development; water scarcity had greatly limited livestock productivity in

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the area. Recently, declining rainfall has accelerated a declining livestock-human ratio, which predictably will fall progressively in time.

Discussion

Stating the Problem

The approach to monitoring used here is widely used throughout East Africa and has become a basic tool in rangeland surveys.[3] In the first instance the objective of the surveys is usually to provide an inventory of resources rather than to resolve a specific problem. In livestock development programs a similar first objective is common. How many animals are there? How are they distributed throughout the area? How do the various species use the area in a seasonal basis? What water and pasture resources are there and how do these change seasonally?

Similar broad questions were asked at the onset of monitoring in Amboseli. Inevitably the questions became more specific with time, and as more interest was shown by government. For example, with the establishment of group ranches it was intended that the pastoral Maasai would abandon nomadism and develop commercial ranches. This has failed to happen and the more difficult question of why has to be addressed. Data from routine monitoring flights has served a useful role in showing that in most cases the continued nomadism stems from inadequate resources on the group ranches.[13]

Efficiency of Monitoring

In the case of Amboseli cost-effectiveness tests were conducted early in the study. Initially counts were carried out twice a month but were later reduced to once a month. The level of sampling was reduced from 25 percent to 10 percent after three years once the main patterns had emerged. Counts will soon be reduced from 6 to 4 per year and only increased again if major changes are detected in seasonal patterns of use.

The initial three years of ground work greatly oversampled vegetation and the level has been reduced by using permanent sample sites rather than randomized samples on each occasion.

Without doubt the nested monitoring system is an efficient design for rangeland surveys since the level of resolution needed can be judged from the sampling hierarchy. The technology involved is extremely simple and repeatable and is applied in various programs in eastern and southern Africa. The return from such monitoring p[illegible] be considered at two levels; the short and long term. In t[illegible] term it provides data of immediate value for planning and policy decisions. Over the long term it provides an assessment of how resources are changing and gives some clues as to causality. The method is now regarded as a low cost technique for providing a surveillance of livestock in rangeland areas.[14]

Organizational Aspects

In Amboseli the Ilkisongo monitoring project has been conducted by independent researchers sponsored by research grants. Fortunately adequate funding has been available to run an efficient project. Elsewhere projects such as United Nations programs in Kenya and Botswana, and government efforts in Kenya, are run by ongoing institutions. The latter are of greater interest organizationally because most large-scale monitoring is likely to be an institutional effort.

The equipment is cheap and the methodologies simple, making the technique accessible to even small government research units. However, equipment is the least of the problems. Personnel have to be trained to a high degree of competence as observers and in many cases organizations seem reluctant to undertake the thorough preflight instructions and calibrations that are necessary. Consequently the quality of observers has be[illegible] Data compilation and analysis can be handled relatively easily [illegible] reduced to routine clerical procedures once the analytical computer programs are available. However, what use is made of the data? It is on the interpretive side that the largest stumbling block is encountered because there are so few personnel trained in exploiting the results for future predictive and planning purposes.

Most organizations have failed to distinguish between the technological and personnel aspects. The technological aspects are transferable, repeatable, and relatively routine. New methodologies can promptly be made available. By contrast, it takes far more time and effort to train suitable personnel, and most international agencies have neglected this aspect. Experts are brought in to establish the program, evaluate the results, produce recommendations and leave. Continuity is impossible.

More effort must be devoted to training teams to an adequate standard. The observers can be efficiently trained by methods currently used by the Kenya Rangeland Ecological Monitoring Unit (KREMU). There each observer is trained to a measurable level of proficiency. But more important is the need for interpretive personnel and planners. An external agency can establish a monitoring program, but who is to evaluate the results for future planning purposes? Such skills are rarely left behind. If monitoring is to be useful in developing countries, we suggest that more effort be devoted to training interpreters and planners.

Institutions such as MARC could play a further role by assembling a variety of techniques and analytical procedures and investigating ways of improving them by, for example, the development of simplified and quantitative measuring techniques and suitable computer and analytical techniques. Such services would hasten the quantification, and hence the accuracy, of monitoring rangeland resources.

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THE MUSSEL WATCH

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A description of the use of mussels as "sentinel" organisms - non-human animals that can be used to measure the levels in the environment of pollutants dangerous to humans.

In 1976 the Scripps Institution of Oceanography, with the support of the Environmental Protection Agency, initiated a modest monitoring program of coastal waters of the United States, utilizing mussels and other bivalves as sentinel organisms. Other laboratories participating in this venture included the Woods Hole Oceanographic Institution, the University of Texas, the University of California at Berkeley, and the Moss Landing Laboratory. About 125 sampling stations were operating during the first year, and the second year program is just beginning.

A variety of some major concerns, some social and some scientific, are involved in the formulation of national or international marine monitoring programs. First of all, there is the identification of those pollutants that jeopardize human health through consumption or exposure; that endanger the well-being of marine organisms or their communities; or that cause the loss of beaches, harbors and estuaries for recreational, asthetic or commercial uses. Four groups of pollutants have received the attention of environmental marine chemists: petroleum; artificial radionuclides produced in the nuclear fuel cycle and in weapons testing; heavy metals such as mercury, lead, cadmium and zinc; and the halogenated hydrocarbons (both those with high molecular weights, such as the pesticides DDT and aldrin and the polychlorinated biphenyls (PCBs), and those with low molecular weights such as perchlorethylene, carbon tetrachloride and the chlorofluoromethanes).

The next concern is to measure the concentrations of these organisms in a specific environment. Although we are primarily interested in the levels in seawater, the measurement of some of these pollutants in seawater is extremely difficult. For example, there are probably not more than a dozen laboratories in the world that can competently measure the high-molecular-weight halocarbons, petroleum, and such artificially produced radionuclides as plutonium and americium. The concentrations are extremely low and demand exacting collection and preparation to avoid contamination. In addition, the instrumentation necessary to carry out the analyses is both expensive and difficult to operate properly. These factors have directed marine scientists to the use of sentinel organisms, marine-creatures that have the marked ability to concentrate from seawater the pollutants of concern.

Probably the most studied of marine organisms with respect to pollutant accumulation is the mussel Mytilus sp. It has already been used in a regional monitoring program sponsored by the OECD for studies of DDT levels in waters off Canada, Denmark, Finland, Netherlands, Norway, Spain, Portugal, Sweden, the United Kingdom and the United States. It appears valuable as a sentinel for hydrocarbon pollution. It rapidly takes up both saturates and aromatics and stores them with little metabolic breakdown. <u>Mytilus edulis</u> rapidly responds to the total hydrocarbon burden of its environment through uptake in its tissues and also rapidly releases such pollutants upon exposure to clean waters. It is known to concentrate heavy metals, including the radioactive nuclides such as zinc-65 and cobalt-60. Plutonium exposure levels appear to be recorded in both the shell and in the soft parts. The transuranic americium is markedly enriched in mussels compared to plutonium. Thus, the mussel can be used to monitor many of the substances cited in the four groups of pollutants so far identified.

<u>Mytilus edulis</u>, a well studied species, is widely ranging in the northern hemisphere and it may be possible to introduce it to places where it does not already occur (though such an introduction would have to be considered with care in advance). Transplantation to areas where the organism is not indigenous has been carried out in San Francisco Bay and off the coast of Southern California. The organism inhabits bays and sheltered coastal areas, and can serve to record environmental levels in such localities. It is a filter feeder and its viscera are compact and easily separable from the shell.

A second group of organisms which appears worthy of consideration as sentinels are the goose barnacles (Lepas). Unlike the mussel, Lepas is an oceanic species, easily caught in neuston nets. Although the 20- or 30-odd species that make up the genus are sometimes difficult to identify, the species inhabiting any one region should be relatively unchanging with time. The goose barnacle is quite cosmopolitan, found in nearly all coastal waters. Less work has been carried out on its body burden of pollutants than for the mussel Mytilus, yet it is now attracting increased attention as a sentinel organism.

How does one identify the laboratories capable of making reliable analyses? Clearly, this must be accomplished by a peer group of scientists. But in addition, the laboratories involved in carrying out the analyses must be in constant communication through intercalibration exercises. Such activities can be carried out by the analysis of standard samples or through the analysis of different splits from the same sample. Such exercises must be carried out at intervals over the surveillance period in order to ensure compatibility of results between laboratories.

In addition there are some problems associated with collection. For the work in the U.S., the mussels are being collected by a single scientist who is traveling the coasts of the United States in a mobil laboratory. Thus collection procedures will be uniform: the organisms will be of similar size, the sexual stages will be identified, and other characteristics that might affect the pollutant uptake or body burdens will be sought. In addition, the collector must not endanger the survival of the existing population. Rather substantial quantities of mussels are required for the analyses of these four sets of pollutants. For the artificial radionuclides, 400 grams of soft tissue are required; for the halogenated hydrocarbons, 500 grams; for petroleum, 1000 grams; and for the heavy metals, 100 grams. In addition, a library sample of around 500-1000 grams should be maintained. Thus around two-and-a-half kilograms of soft tissue, or about 5 kilograms of mussels, are necessary. In certain areas of sparse mussel populations, the removal of five kilograms might be unwise.

For the U.S. sampling program, the following guidelines are being used. Composite samples of mussels from about ten locations in each area are sought. Mussels from rocks are preferred to those living in sand or mud. Samples from buoys are not taken because metal contamination might occur. Where two species of mussels are found in an area and both are involved in analyses from other areas, both are collected for assay to ascertain species differentiation in pollutant uptake and body levels. The locations of the sampling sites are based on accessibility and reasonable geographical distribution.

Economic considerations determine how many sampling sites can be operated in a year. Our preliminary analytical costs are: petroleum hydrocarbons, $860 per sample; artificial radionuclides, $300 per sample; chlorinated hydrocarbons, $100 per sample; and heavy metals, $40 per sample. Thus, analytical costs total about $1,300 per sample. Collection costs will probably be of the same order of magnitude or a little less. Collection and analytical costs will probably be of the order of $2,500 per sample. For one thousand samples on a global basis, the mussel/barnacle watch would involve $2,500,000.

How does one involve the best laboratories and the most competent scientists in such programs? The key is to let the designated scientists propose the strategies of surveillance, carry out the analysis of the data, and interpret the results to those responsible for environmental management. For the scientists there is not only the satisfaction of involvement in a substantial undertaking, but also the strong possibility that their own research will be expanded through additional studies and facilities and through cooperative ventures with other participants in the project.

Finally, what are the values of the mussel watch? For a given ocean area there will be trends in the pollutant concentrations over the sampling period; probably samplings will be done yearly. In addition, it may be possible to predict future pollutant levels in the waters with the knowledge of present-day dispersion of the pollutant and estimates of future emissions. Without such information, the management of pollutants contaminating ocean waters becomes inordinately difficult, if not impossible.

THE WMO WORLD OZONE NETWORK

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Stratospheric ozone measurements are made regularly in a number of countries. These national activities are co-ordinated by the World Meteorological Organization (WMO), which arranges for intercalibration of instruments and decides on methods of quality control. The data are published on behalf of WMO by the Atmospheric Environment Service, Downsview, Ontario, Canada.

In this paper, the history of the World Ozone Network is traced, and its relevance to current problems is discussed.

Historical Perspective

The early history of the ozone network has been described by Dobson (1968). As early as 1880, Hartley suggested that atmospheric ozone was absorbing ultraviolet sunlight. However, the first accurate ground-based measurements of total ozone were not made until 1920, when Fabry and Buisson determined the amount of ozone over Marseille, using a spectrographic method. Further measurements were made by Dobson at Oxford, England on sunny days in September-October 1924 and again in February-December 1925. The observations showed an annual cycle, with highest values in the spring. The reason for this behavior was not known, but there was so much interest in the project that, with the help of the Royal Society, a European network was established in July 1926 (Oxford, England; Valencia, Ireland; Lerwick, Scotland; Abisco, Sweden; Lindenberg, Germany; Arosa, Switzerland). All stations were supplied with photographic plates, which were mailed back to Oxford after exposure. By the end of 1927, more than 5,000 observations had been made. In 1928, four of the instruments were moved in an effort to determine global patterns from the following network: Oxford, England;

Arosa, Switzerland; Table Mountain, California; Helwan, Egypt; Kodaikanal, India; Christchurch, New Zealand. The 1928-1929 data established the six-month difference in phase between the two hemispheres, as well as the latitudinal gradients of ozone (ozone values increase with increasing distance from the equator).

The prototype of the modern ozone spectrophotometer was built in England in 1929. For the first time, the ozone amount could be calculated in situ without the delay associated with mailing photographic plates to Oxford. About 110 of these "Dobson" instruments were manufactured in the next few years, and most of them are still in service.

In 1929, Gotz realized that from measurements of total ozone at two wavelengths and at several sun elevations on a clear day, it was possible to infer the average height of the ozone layer and to provide a general indication of the vertical distribution of ozone. This technique, known as the Umkehr method, provided a stimulus for many research studies in the 1930's and 1940's.

The first international conference on stratospheric ozone was held in Paris in 1929. This led to the formal involvement of international scientific organizations in 1930, when a Sub-Commission on Ozone was established within the International Union of Geodesy and Geophysics of the International Council of Scientific Unions. After the war, a separate International Commission on Atmospheric Ozone was organized. Its main task in 1948 was the "organization of an ozone survey for Western Europe, while at the same time assisting in the establishment of ozone stations in other parts of the world, as opportunity presented itself."

In the 1950's, chemical methods for measuring ozone were developed, making it possible to obtain in situ values from aircraft, balloons (ozonesondes) and rockets. An intensive monitoring program was undertaken during the International Geophysical Year in 1957-1958, coordinated by the International Ozone Commission and, in particular, by its Secretary, Sir Charles Normand. Up to 1959, new ozone instruments were adjusted and tested in Normand's laboratory at Shotover, near Oxford, England. As Dobson (1968) remarked, however, "the work at Shotover, being on a private basis, could not be permanent, nor did it lend itself to the expansion which could be envisaged in future years.

At the beginning of the work, an informal organization was necessary, but as more and more people became interested, a much more permanent organization became necessary." It was therefore quite natural that the WMO should assume responsibility, publishing the results of the IGY ozone program and establishing the World Ozone Network. In 1959, Normand resigned as secretary of the International Ozone Commission, and the work at Shotover was greatly reduced.

The network had been sustained during the 1930-1960 period by a group of scientists whose enthusiasm was pervasive. At first, there had been hope that better understanding of the stratospheric ozone layer held the key to better weather forecasts. However, the main impetus for continuing the program over three decades was scientific curiosity: each set of measurements provided new information, e.g., concerning the interplay between the photochemistry and the dynamics of the stratosphere. It is nevertheless surprising that the network remained active for such a long time without much encouragement, or interference, from governments. Monitoring systems rarely persist unless they prove to be of practical value (e.g., in warning of disasters) or in predicting favorable environmental conditions (e.g., those that optimize agricultural yields or aircraft flight plans).

In the late 1950's, when the WMO accepted responsibility for the network, some practical reasons for monitoring ozone had finally emerged:

a) There were growing numbers of space applications in which a knowledge of the structure of the middle and upper stratosphere was required (e.g., in connection with rocket reentry calculations).

b) There was public concern about nuclear bomb testing, and information was being sought about stratospheric motions and about the exchange rates between the Northern and Southern Hemispheres, as well as between the stratosphere and the troposphere. Ozone had been found to be a useful tracer for these investigations.

c) Numerical models of the general atmospheric circulation were being developed, and these required stratospheric inputs. There was a growing belief that data from the World Ozone Network could contribute to the development of more realistic models, and thus to improved weather forecasts.

Description of the World Ozone Network

The Canadian Atmospheric Environment Service publishes "Ozone Data for the World" (issued annually for the years 1960-1964; bimonthly thereafter). The data are also available at cost on magnetic tape.

The following information is included in the publication:

a) total amounts of ozone on indicated days and hours at indicated locations (based on measurements obtained mainly with the Dobson instrument);

b) observations of the Umkehr effect, and resulting estimates of the vertical distributions of ozone (based on measurements obtained with the Dobson instrument);

c) vertical distributions of ozone obtained from ozonesonde observations;

d) a few measurements of surface ozone.

An observer's handbook was written for the Dobson instrument (Dobson,), and operations manuals have been prepared by several countries, e.g., U.S.A. (Komhyr, 1961) and Canada (COOM, 1973). Meteorologists have had long experience (more than 100 years) in the design and operation of observing networks, and they are well aware of the need for standardization of observing procedures, intercalibrations and quality control of data.

Some details concerning the network are given in Table 1. The bottom row of the table reveals that the number of stations rose from 43 in 1960 to 103 in 1967, diminishing to about 75 in the last several years.

The geographic distribution of stations is uneven. The Northern Hemisphere is well represented, but there are few observations from Africa and South America. From the point of view of a world network, this imbalance is amplified by the much larger fraction of the world's oceans

Table 1: Ozone Data for the World;

Number of Stations Reporting One or More Observations*

	Year 60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
ANTARCTICA																
Total Ozone	4	6	7	6	5	6	7	5	3	3	3	3	3	2	1	1
Umkehr	2	2	4	3	3	3	3	2	2	2	2	2	2	0	0	0
Ozonesonde	0	0	2	3	2	3	4	1	1	1	1	0	0	0	0	0
AFRICA (WMO REGION I)																
Total Ozone	2	2	2	2	2	2	2	2	2	2	3	3	2	1	1	2
Umkehr	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
Ozonesonde	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASIA (WMO REGION II)																
Total Ozone	12	15	19	27	31	34	37	37	24	25	24	24	24	24	24	25
Umkehr	5	4	4	8	9	10	9	8	9	10	9	9	9	9	9	9
Ozonesonde	0	0	0	0	0	0	0	0	0	3	3	3	3	3	3	0
S. AMERICA (WMO REGION III)																
Total Ozone	0	0	0	1	2	3	2	2	2	2	2	2	2	2	2	2
Umkehr	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ozonesonde	0	0	0	1	1	3	2	0	0	0	0	0	0	0	0	0
N. AMERICA (WMO REGION IV)																
Total Ozone	5	5	6	14	16	16	15	17	16	15	15	13	13	14	15	15
Umkehr	5	5	5	6	7	7	3	3	4	5	6	6	5	2	0	0
Ozonesonde	0	0	2	14	14	13	3	1	1	2	2	3	2	2	1	2
AUSTRALASIA (WMO REGION V)																
Total Ozone	4	5	3	4	5	6	7	7	8	8	9	8	8	8	8	8
Umkehr	1	1	3	4	3	3	3	3	4	5	4	3	4	0	0	0
Ozonesonde	0	0	0	0	1	4	1	1	1	1	1	1	1	0	0	0
EUROPE (WMO REGION VI)																
Total Ozone	16	20	24	26	27	29	31	33	26	27	28	25	23	23	22	23
Umkehr	1	1	1	3	4	4	3	4	4	4	4	4	4	4	4	4
Ozonesonde	0	0	0	1	2	4	5	5	5	3	4	[illegible]	4	[illegible]	1	2
Number of Stations Reporting At Least Total Ozone	43	[illegible]	61	80	88	96	101	103	81	82	84	78	75	74	73	76

*Table prepared by A. W. Smith.

in the Southern than in the Northern Hemisphere. Apart from a few stations at island locations, there is no network coverage of oceanic regions.

The number of Umkehr stations is a small fraction of the number of total ozone stations.

Finally, the number of ozonesonde stations is small, with the exception of North America in the years 1963, 1964 and 1965.

One of the effects of ozone depletion would be an increase in the amount of ultraviolet (UV) solar radiation reaching the surface of the earth (assuming no change in climate). The Australians have a small network of UV instruments, and the Americans have recently installed sensors at 17 locations. At the present time, the WMO is considering the design and intercalibration of a UV sensor that could be recommended for universal use.

The Modern Challenge

Beginning in 1970, the possibility that the ozone layer might be perturbed by emissions from supersonic aircraft began to be discussed, as well as the consequences of such perturbations on world climate and on the UV radiation reaching the earth's surfaces (see, for example, SCEP, 1970). In 1974, halocarbons (from aerosol spray cans and refrigerants) were implicated as a threat to ozone depletion. In 1975, nitrogen fertilizers also came under scrutiny.

These concerns attracted the attention of the news media, which were quick to inform the public. Munn and Rodhe (1975) have described the rapid rate of transfer of new information on ozone depletion. The first scientific paper on the possible effects of spray-can aerosols appeared in Nature on 28 June 1974 (Molina and Rowland, 1974), followed by a paper in Science on 27 September 1974 (Cicerone et al., 1974) and an article in Time Magazine on 7 October 1974. Then on 25 October 1974, in an episode filmed about a week earlier, the popular television comedy series "All in the Family" brought the scientific problem to a North American mass audience in a surprisingly well-informed way, less than 4 months after the first report in Nature! In the opinion of some scientists, the rate of transfer of scientific information to the general public in North America and western Europe is now too fast.

The scientific literature on ozone depletion has multiplied rapidly since 1970. The main emphasis has been on the development of mathematical models of stratospheric photochemistry, together with associated experiments (in both the laboratory and the stratosphere) that are required to verify the models.

Additionally, investigators have been interested in determining whether the World Ozone Network shows any indication of trends. Mankind's inputs of halocarbons and N_2O have been increasing, so the possibility needs to be checked that ozone depletion has already begun. This is not an easy problem to solve because of the great natural time and space variability in stratospheric ozone, coupled with the occurrence of time and space correlations in ozone data sets. As discussed by Pittock (1974), the network deficiencies in the Southern Hemisphere, the tropics and the oceanic parts of the Northern Hemisphere make it difficult if not impossible to separate regional trends (due to longitudinal shifts in the positions of the long-wave pressure throughs) from global ones. Kulkarni (1976) agrees, concluding that the changes in the general circulation in the lower stratosphere during 1963-1974 are sufficient to explain the observed ozone trends at four Australian monitoring stations. In fact, Pittock (1974) estimates that if there were a sudden 2 percent depletion of stratospheric ozone, an additional 10 years of observations would be required before the event could be confirmed with 95 percent confidence. See also [illegible] et al. ([illegible]) and Hill et al. (1977) for recent discussions of the problem of determining ozone trends.

These remarks are not to be construed as criticism of the World Ozone Network, which was not designed to determine trends. The uneven spacing of stations, with large gaps over the oceans, is quite understandable, and is a common deficiency in almost all international monitoring systems. This is because each member state has the right to decide whether to establish monitoring stations. Even if financial assistance were offered, in fact, a country might still choose to stay out of a program.

Finally, reference should be made to a comment heard from time to time that the World Ozone Network is practically obsolete because of advances in satellite technology. Total ozone was measured on Nimbus 4 using a back-scatter ultraviolet sensor, and additional experiments are planned. However, the World Ozone Network must continue to operate for the following reasons:

a) the accuracy of satellite measurements is not sufficient for studies of long-term trends in total ozone, although the observations provide useful information on day-to-day and latitudinal/longitudinal variations;

b) even if the accuracy of satellite measurements were improved, the World Ozone Network would still be required for ground-truth comparisons;

c) because the lag time between planning and launching a satellite is long (7 years or more), the system cannot respond quickly to newly perceived needs (special geophysical experiments, for example).

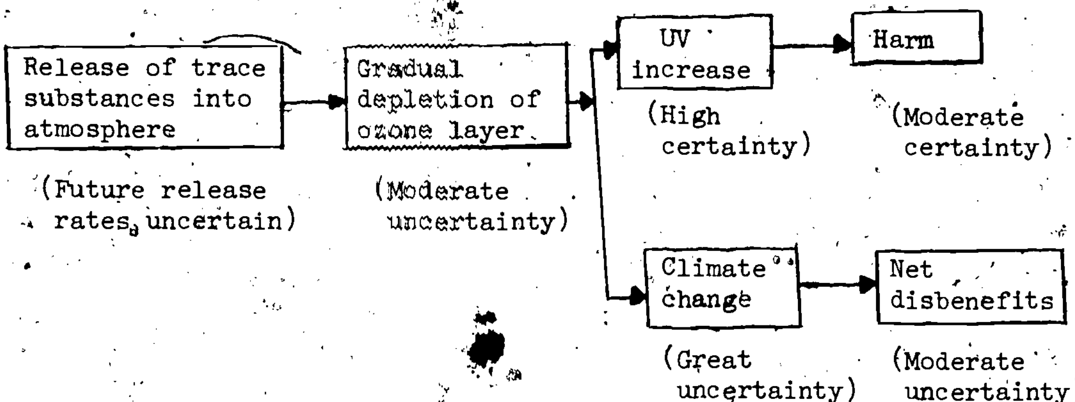
The Response of WMO to the Challenge

Ever since 1957, the WMO has continually urged member states to participate in the World Ozone Monitoring Program, and has supported the activities of the ICSU International Ozone Commission. For example, a grant from WMO permitted an international comparison of Dobson instruments to take place in Poland in 1974.

In September 1975, a WMO Working Group on Stratospheric and Mesospheric Problems met in Geneva to review the latest developments and to recommend further action. As a follow-up, an Ad-Hoc Expert Meeting on Ozone was held in Toronto, 12-16 January 1976, when a WMO proposal for a Global Ozone Monitoring and Research Project was drafted. The proposal was subsequently approved by the WMO Executive Committee at its 28th Session in the spring of 1976 (WMO, 1977). The detailed recommendations call for an expanded World Ozone Network.

Cost-disbenefit Relations

In connection with the ozone problem, the question of cost-disbenefit relationships is worth examination. Depletion of the ozone layer would cause an intensification of UV-radiation at the surface of the earth, and could also cause climate change. The resulting disbenefits would amount to billions of dollars. The linkages are shown in the flow diagram below, and some relative uncertainties are suggested.



In comparison with the very large disbenefits that would accrue from ozone depletion, the cost of operating the World Ozone Network is trivial. Even if the funding required for research programs were added, the sum would still be a minute fraction of the cost of the possible disbenefits. Having said this, however, it should be added that if the policy makers were to take no action (other than funding research) until data from the monitoring network had demonstrated that ozone depletion had begun, it would already be too late to avoid disbenefits.

This is not to denigrate the value of ozone monitoring programs, which are important for the following reasons:

a) if ozone depletion became sufficient for effects to become apparent, monitoring would provide information on the magnitude of the depletion, and would aid, for example, in deciding whether there were a serious risk of skin cancer if the human body were not protected from sunlight;

b) monitoring, particularly of processes, aids in the testing of theories of ozone depletion and of resulting effects and in the development of better predictive models.

In terms of these two objectives, the cost of the network is still a trivial fraction of the resulting benefits that might accrue. In this connection, however, an important point should be made. If the primary objective of the network is model building rather than trend analysis, the design criteria are different and, in several senses, more difficult to apply. For example, there is need to monitor the chemical species that are reactive in the stratosphere, as well as the ozone concentrations themselves. It is thus essential that the scientific community (ICSU, International Ozone Commission) continue to have a strong voice in the future development of the World Ozone Network, perhaps through a GARP-type institutional structure.

<u>The Future</u>

UNEP held an inter-governmental meeting of experts 1-9 March 1977, "...to review all aspects of the ozone layer, identify related ongoing activities and future plans and agree on a division of labor and a coordinating mechanism for <u>inter alia</u> the compilation of research activities and future plans and the collection of related industrial and commercial information, and to report to the Governing Council at its fifth session on the results of the meeting." The future of the World Ozone Network was discussed at that meeting; and the WMO made a strong case for strengthening the network (WMO, 1977). These proposals were supported in principle (UNEP, 1977), as indeed they should be for the reasons given above.

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MERCURY MONITORING IN SWEDEN

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The risks of mercury (Hg) are largely attributable to alkyl-mercury because of the special properties of the latter molecule. This is equally true in the case of ecological risks to both terrestrial and aquatic systems, as well as to human health. The story of these findings has been told in several instances both scientific[1,11] and popular.[12] This paper will emphasize the lessons for mercury monitoring derived mainly from the Swedish experience. The time covered is mainly 1963 to 1970.

Statement of the Problem

In 1963 there were at least four major elements in the mercury situation in Sweden:

a) the suspicion, arrived at independently by professor Karl Borg and the late Erik Rosenberg,[3] that the paralysis and death of birds and mammals were connected to mercury used as seed-dressing agent;

b) the book by Rachel Carson, Silent Spring, which stirred interest in the ecological concentration of pesticides such as DDT;

c) the laboratory work of S. Tejning and R. Vesterberg on hens fed with Hg-treated grains, resulting in high Hg-levels in eggs;[4]

d) some knowledge, although sparse, of the Minamata and Niigata tragedies. Kurland's paper was the main source since the original Japanese publications were not translated into Swedish until later.

The Ecology Committee of the Natural Science Research Council had taken initiatives during 1963, partly as a result of Carson's book. The Ecology

Committee formed a Nature Resource Committee (NRC) which got some government money to start with. 75,000 Sw. Crs. were devoted to DDT-analyses and the same sum to total mercury in 1964.

How Was the Problem Defined?

Initially, no clear problem was recognized. Scientists merely wanted to shed light on the possible spreading of man-made pesticides, including Hg seed-dressing agents. A smaller group, chaired by Dr. B. Lundholm, was named by NRC. This group included two of the present authors, Alf G. Johnels and Torbjorn Westermark, as well as professors K. Borg and G. Widmark. Dr. G. Otterlind also took part as representative of the ornithologists in Sweden, who were alarmed by the large losses of terrestrial birds of prey, and especially seed-eaters like the yellow and ortolan bunting.

The group selected samples from several bird species, some seed-eaters and some herbivores (wood pigeon, hooded crow, yellow bunting, pheasant, starling, mallard, white wagtail, black-headed gull, pied fly-catcher).[6] This choice is in hindsight important from a monitoring point of view. Samples were sent to Westermark's laboratory for analysis of both DDT and total mercury. It was decided to look for mercury in breast muscle and liver, and sometimes kidney and eggs. The samples were collected from all parts of Sweden in a systematic manner. The field and preparatory work was performed by the Natural History Museum. All specimens were put in deep-freeze for future use after samples were taken.

Simultaneously, two other monitoring endeavours took place:

a) birds and mammals found dead were analysed by K. Borg and his colleagues; pathological and chemical investigations were performed and factors were sought to shed light on the cases;[7]

b) food bought on the open market was analysed for mercury and later DDT by Dr. Gunner Westoo at the Institute of Public Health.[8]

Did the Formulation of the Problem Evolve with Changing Circumstance?

Yes, indeed so. Initially, the efforts were limited to:

a) analysis of total mercury, giving no information on chemical compounds of Hg (except for some indications given by the Hg quotients of levels in, say, liver as compared to breast muscle);

b) mainly terrestrial biota;

c) human food of certain types (mostly eggs and meat);

d) mainly terrestrial birds and mammals found dead.

The scope was eventually widened in several important ways. The discovery of mercury in fish in significant concentration[9] came about because it was felt that the ecological program, though rewarding, was too narrow. Drs. Westermark and Johnels and Dr. B. Lundholm in April 1964 happened to discuss the possibility that Hg as a seed-dressing agent would perhaps be transported by soil water from agricultural areas to fresh water and then be concentrated in fish. Johnels suggested analysis of mercury in pike because that fish would integrate to some extent both in time and space, since it preys on other fish and grows most of its life. Furthermore, pike is rather stationary. A lot of other biota, like earth-worms, rodents, vegetables, birds of prey and (very usefully) feathers of birds, were also included.[10] The provisional permissible Hg concentration was at that time 50 ng/g. But concentrations up to 6,000 ng/g were found in pike, showing immediately a serious situation with figures approaching those found in Japanese fish that had caused tragedies.[5]

Soon the causal relations were identified. Preservation of wet pulp with Hg-phenyl-acetate was shown to be the source of very high mercury concentrations in fish by analysing mercury in pike upstream and downstream from factories with dams or other hindrances to fish migration. Also, the caustic-chlorine industry was found to be a cause of elevated Hg levels in fish. Later, many other sources were identified, including the city of Sotckholm, the electrical and pyrite industries, paint manufacturers, etc. The seed-dressing mercury was hardly a significant source of mercury in aquatic biota.

The idea of analysing feathers from museum specimens was very rewarding. Feathers dating back more than 140 years were analysed at the Swedish Museum of Natural History. Birds of prey especially showed convincingly that mercury levels in terrestrial birds were very elevated from 1940 to the time we worked; and aquatic birds (osprey, sea eagle and crested grebe feeding on fish) had a more gradual rise starting perhaps 1900-1920.[10]

It occurred to Westermark in April 1965 that Denmark did not have losses or dead birds like Sweden. The Danes used alkoxy-alkyl-Hg instead of methyl-Hg.[11] Later on (September 1965 J. C. Gage's paper[12] revealed that methyl (and ethyl) mercury did not decompose in mammals but alkoxy-alkyl (and phenyl) did. The latter compounds behave more or less as inorganic ionic mercury, as shown by toxiocological studies[12] and by analytical chemistry.[9]

In this manner, an understanding of the mercury problem on the terrestrial side developed before 1965. The announcement on November 30, 1965, by Dr. G. Westoo that the main part of mercury in fish was methyl-Hg came as a shocking surprise.[13] In the beginning of 1967, Drs. S. Jensen and Arne Jernelov showed that microbial methylation was most probably the route. Mercury as metal, ion, and phenyl-acetate all end up as methyl-Hg in fish, flesh and other organs. Dr. Westöö's extensive analytical monitoring in fish showed that this was a quite general situation in fish and shellfish from all sorts of water, including the sea.[13]

Obviously, the original monitoring program, though yielding quite clear results, was nearly completely superseded by new and perhaps more important findings. Especially it was clear in 1964-1965 that men feeding on fish might be in danger; extreme fish-eaters ("human grebes") might approach the lethal levels observed in Japan.[15]

Types of Monitoring and Variables Used to Obtain the Basic Data

Total mercury was determined mainly by activation analysis on carefully selected biota, mainly birds of different feeding characteristics (seed-eaters, insect-eaters, carnivores, etc.). Samples were taken in different regions of Sweden and different types of landscape from various organs, such as muscle, liver, egg and kidney (total organs, with no effort to go "microscopically"). The monitoring also included systematic mercury analyses of foodstuffs bought in the open market over the whole country as well as complete meals. Eggs were the main object of interest in the beginning;[8] later the efforts were extended to meat, fish, shellfish.[13] Dead birds and animals were continuously analysed for total mercury by Professor K. Borg[7] of the State Veterinary Institute.

The three branches had rather good contacts with each other through committees and numerous conferences. In hindsight, the coordination was far from fully effective and much competition among the "territories" occurred. Gradually, not only mercury was determined but also methyl-Hg. Even later on, analyses of man himself were initiated.[16] The Swedish efforts were wide indeed, including more than ten sciences.

Efficiency and Quality of the Monitoring Process

The sampling in nature was made with much skill. Keen ornithologists and museum biologists were engaged and were very active in sampling and in other ways like preparing censuses. The preparation of samples was made in an over-cautious way (Hg-free laboratories, testing of air, water and tools). Gradually, these precautions were found to be unnecessary. We found that we could deal readily with samples of a few ppb (ng/g) of mercury without contamination.

Activation analyses of total mercury in biological samples were well worked out by Torbjorn Westermark and B. Sjöstrand.[11] The analyses were later found to be very accurate when intercalibration work was done, both in Sweden and internationally. With regard to quality of results, this method has defended itself well against several competitors, including atomic absorption methods. In the references, many intercalibration efforts are indicated.[17]

From 1966 onwards, Dr. G. Westöö's procedure for analysing for methyl-Hg was established.[13] Here too, intercalibrations were made by a special working group and fairly good results were obtained. Much work was devoted to confirm the identity of methyl-Hg by independent methods like gas chromatography, mass spectroscopy and concentrating electrophoresis.

Finally, in many samples the quotient methyl-Hg to total Hg was important and was obtained in addition to total Hg. Other mercury forms like phenyl-Hg were studied, but they did not achieve a place in the monitoring programs.

Adequacy of the Organization, Including Coordination Between Participating Institutions

Although the different efforts in Sweden were not well coordinated at the time described, the meetings and conferences as well as the oral reports to the government, and perhaps the invisible element of competition, made the whole effort quite satisfying. A strong organization might have spoiled the necessary flexibility and freedom of the laboratories. Even after 1966 several further initiatives had to be taken: insight into mineralogy and geology and their connection to ecology, more detailed studies on lowering of emissions from dozens of factories, much more information on toxicology for methyl-Hg in "free" form and protein-bound form, and more human toxicology.[16] By 1970, only one major field - air emission, transport and fallout - was hardly touched. At the same time, few of the studies were "deep" in the sense of, say, ordinary biochemical research.

Translating the Results into Policy

The alarming mercury findings were kept from the public for more than a year. Frequent reports were sent to several authorities, until the government named a commission in 1964 to take over administration of the mercury research. Later on, after the commission's 1968 report, the Nature Environment Protection Board was formed.

Two of the present authors met with members of the government and the directors-general for medical welfare, the institutes of food and health, of fisheries, and several agricultural and veterinary institutes. The experience of making direct reports to policymakers in this manner was new to us as researchers. It was also strange to have the Minister of Agriculture ask our views on the alternatives for government action. One could ban all freshwater fishing in Sweden, black-list part of it (determined by a certain mercury level in fish) or just issue recommendations not to eat fish from certain waters (especially not children and pregnant women). As you know the black-listing route was followed. The limit was set at 1 mg/kg of mercury. So the monitoring results, especially the mercury level in pike, were extremely useful in the administration procedure. Later on, when the same waters got cleaner, the monitoring results were used in decisions to remove prohibitions.

In the terrestrial field, the government decision was formally very simple: just replace alkyl-mercury with alkoxy-alkyl-mercury as seed-dressing agent. Alkoxy-alkyl-Hg works well as a seed-dressing agent, (using the same techniques as alkyl-Hg) and decomposes to inorganic mercury rapidly in birds and mammals. This suggestion and a summary of the ecological evidence were put forward on November 19, 1965.[32] A decision in this direction was taken by the Pesticide and Poison Board in late autum 1965. The story told by mercury in museum bird feathers certainly played a role.[10] Already, in the spring of 1966, the young of some birds had much lower mercury levels.[18] After some years the terrestrial situation got much better, but mercury levels perhaps remain somewhat elevated as compared with those of 100 years ago[18] (see figure 2). Also, eggs and meat improved.[19] In people eating great amounts of fish, a diet of ordinary food caused the mercury levels, as judged from Hg-analysis of blood and hair, to decay gradually[16] (see also figure 3).

Another example of policymaking: we found very high mercury levels, up to 6,000 µg/g in pike in the Mörrumsån River in southern Sweden.[9] This was discovered on June 20, 1965. One of the authors phoned Dr. H. Bouveng, then at IVL, who in turn phoned to the manager of a pulp factory on the river where phenyl-Hg had been used and emitted for ten years. This factory was the sole source. Before the afternoon of the same day, the emission was stopped forever. Figure 1 shows examples of the very satisfying decay after that time.[18]

With Hindsight, Could the Same Effectiveness Have Been Achieved With A Reduction of the Monitoring and Assessment Activities?

Approximately 50,000 mercury analyses were performed in 1964-1971.[11] In hindsight, it is striking that after perhaps a thousand analyses, the right conclusions were already clear. Various interests in the country, however, wanted to have their own areas monitored, and so a much larger mass of information had to be gathered. In late 1967, a mercury analysis report was published[20] with a mass of fish data from many parts of the country. This report convinced everyone that we had a mercury problem. The reaction in newspapers, radio and television, already strong, increased a great deal. So we think the monitoring program reached about the right magnitude, but scientific understanding did not require so much. Even 10 percent of the effort might have been sufficient from the scientific point of view.

Have the Results of Monitoring Given Rise to Political Issues and to What Extent Have These Been Affected or Resolved by the Assessment Process?

Mercury was an issue in Sweden from 1964 to at least 1971. As seen above, important decisions were:

a) the ban of alkyl-mercury for seed-dressing purposes (1965);

b) the ban of phenyl-Hg in pulp and paper treatment (about 1966);

c) the establishment of a maximum permissible Hg concentration in fish to be sold (one mg/kg fresh weight[21]) and "black-listing" of waters by the authorities.

Together with this last decision, a recommendation of limited intake was issued.

Further, large reductions of the emission of mercury to the environment from all sources was the goal of many administrative rules and decisions. The IVL Laboratory and industry made important efforts in industrial technology and the purification processes. This resulted in reduction of mercury emissions to the waters by a very large factor.[31] Moreover, the choice of industrial processes was affected. The government's environmental policy encouraged - by beneficial loans, for example - one new and one old chlorine-alkali plant to abandon the mercury process for the diafragma method (avoiding asbestos membranes). The mercury case, we think, was important (along with DDT, PCP, SO_2, etc.) in forcing legislation aiming at a cleaner environment. Rules not only for emissions but also for product control were established. With the projected increase in coal burning, Sweden faces a mercury problem again.

During many years, the sales of fish, including marine fish, went down sharply. Lake fishermen left their jobs. The export from Sweden to Denmark of some suspect food, such as pheasants, was affected. It was feared that export of food would continue to be difficult, but after some years normal conditions returned.

Countries such as the U.S. and Canada sent government delegations to Sweden to discuss the mercury problem. Similar cases have occurred in Japan, Iraq, the U.S. and Canada.[29] The export and import of some foodstuffs like tuna have been discussed internationally. The high mercury level in tuna is apparently natural, and its effects are counteracted in human metabolism by the high selenium level.

The case of mercury, and especially its ability to be transformed in nature to an organic and potentially toxic compound, has analogies to other potentially toxic metals.[22] The description of these and the concern about carcinogenic action lie outside this paper. A few references to such work are, however, included.[23-30]

<u>Summary</u>

The mercury case taught us very much indeed. When a problem comes up requiring monitoring efforts, one should, we think, organize the sampling in terms of ecological principles, i.e., study organisms on various trophic levels (up to animals of prey and man) and of different characters (insect eater, herbivores, etc.). First, the problem or problem pattern has to be resolved, and then more routine monitoring started. Some part of the budget should be flexible (also in the monitoring phase) and the workers should feel free to discover new things. In the mercury case, there were examples of irritation within the government, which was apparently not prepared to face a situation like this one. In several respects, the situation is now much improved in handling similar environmental problems.

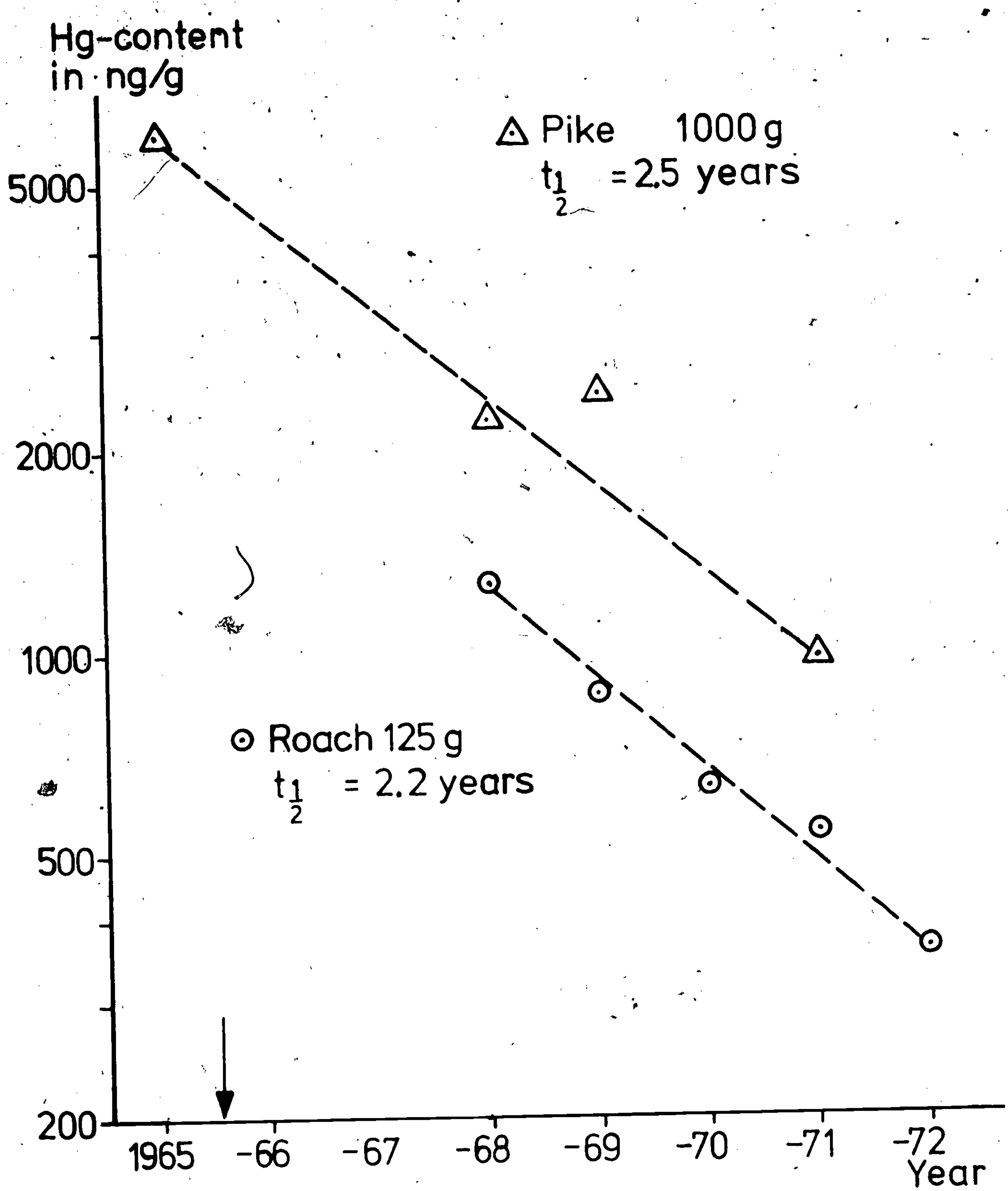

Figure 1: Decay of mercury levels in pike (upper curve) and in Mörrum River (lower curve) since the end of emission (half-life ca 2.5 years).

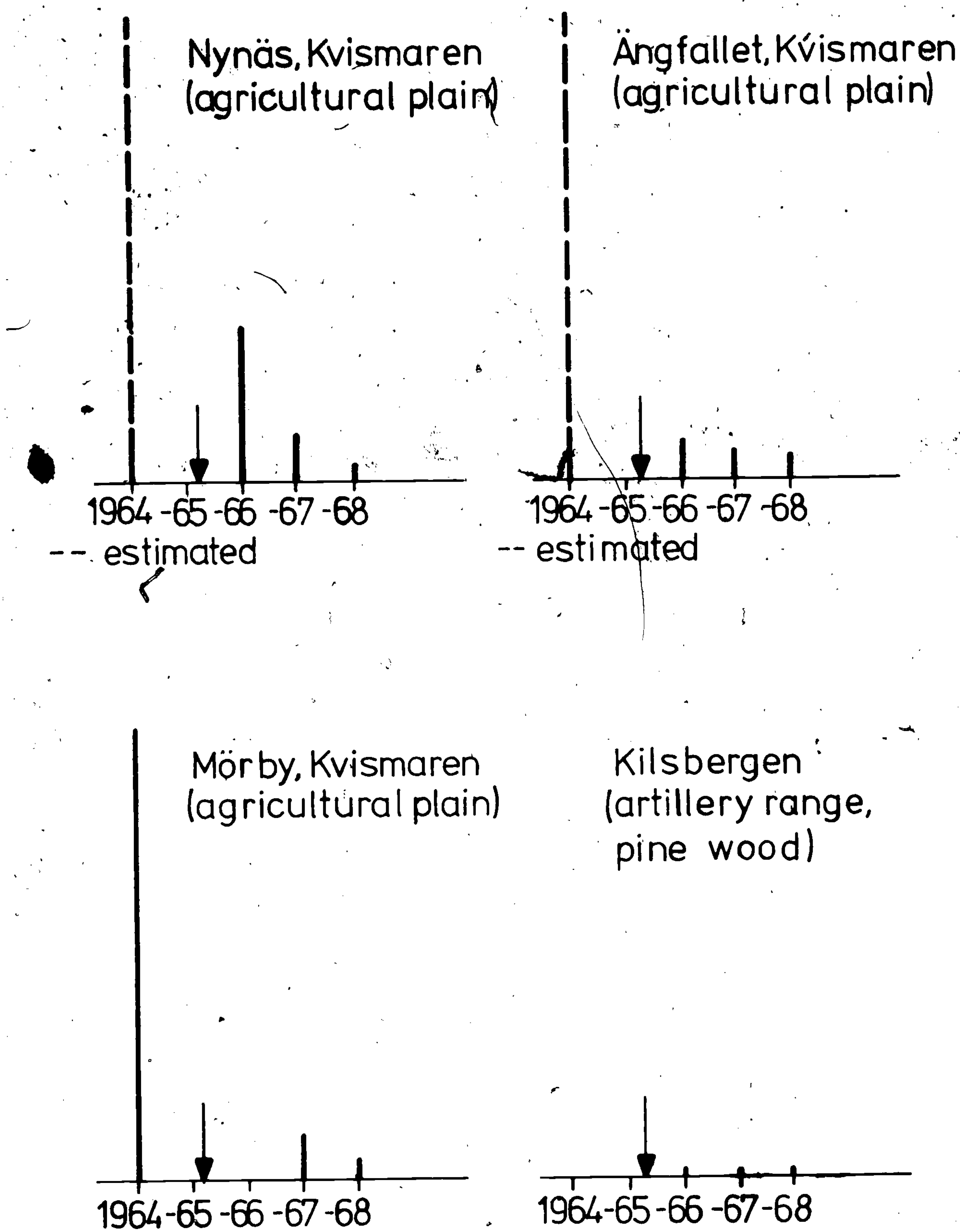

Figure 2: Mercury in breast muscle of starlings in Sörmland after the ban of alky mercury in 1965 (lower right is a pine wood area many miles from agriculture).

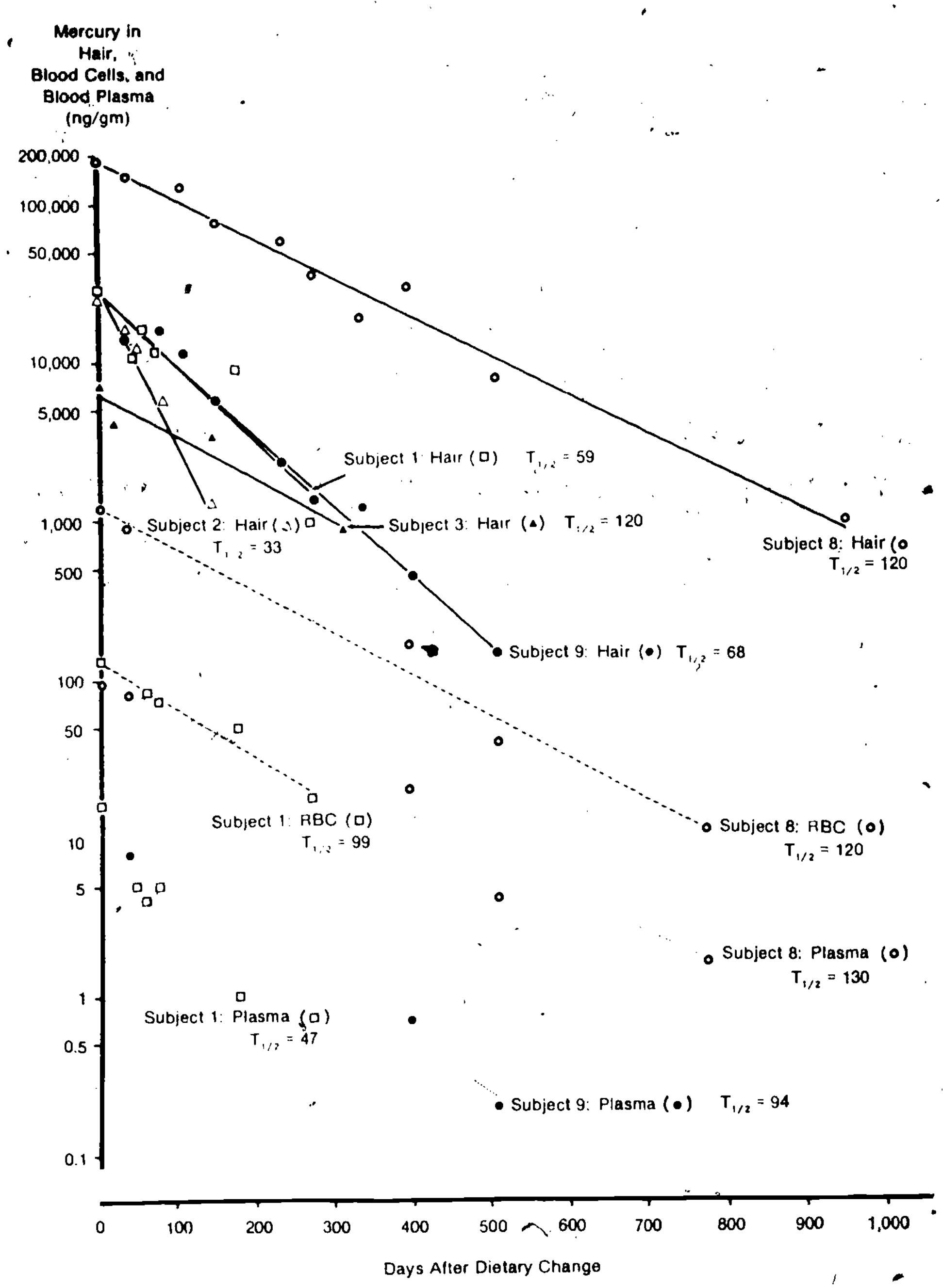

Figure 3: Elimination of total mercury from hair, blood cells, and plasma in five subjects exposed to methyl mercury through intake of contaminated fish after dietary change to low fish intake or to mainly ocean fish, or to both. Steady states observed after the decay curves have been subtracted. (Courtesy of Archives of Environmental Health, Vol. 25, August 1972.)

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